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**REVISED DRAFT FINAL  
REMEDIAL INVESTIGATION REPORT  
Q Area Drum Storage Yard  
Norfolk Naval Base  
Norfolk, Virginia**

Prepared for:

**Atlantic Division  
Naval Facilities Engineering Command  
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## List of Acronyms and Abbreviations

ARARs	applicable or relevant and appropriate requirements
atm-m <sup>3</sup> /mole	atmosphere-meter <sup>3</sup> /mole
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BCF	bioconcentration factor
BDL	below detection limits
BNA	base-neutral-acid
°C	degrees Celsius
CERCLA	Comprehensive Environmental Recovery, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm	centimeter
COCs	contaminants of concern
COPCs	contaminants of potential concern
CSF	cancer slope factor
DCA	dichloroethane
DOT	Department of Transportation
ECAO	Environmental Criteria and Assessment Office
EIC	Engineer in Charge
EPA	Environmental Protection Agency
EP TOX	Extraction Procedure Toxicity
EQ	ecotoxicity quotient
EY	Truck and Equipment Storage Yard
ft	feet
FP	Fleet Parking
g	gram
gpm	gallons per minute

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ha	hectares
HEAST	Health Effects Assessment Summary Tables
HI	hazard index
HM	Hazardous Materials Area
HQ	hazard quotient
IAS	Initial Assessment Study
ID	inner diameter
IOC	inorganic compound
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
K	hydraulic conductivity
Kd	Absorption Coefficient
kg	kilogram
L	liter
LANTNAVFACENGCOM	United States Navy, Atlantic Division, Naval Facilities Engineering Command
LOAELs	lowest observed adverse effect level
m	meter
MCGL	maximum contaminant level goals
MCL	maximum containment level
µg	microgram
µm	micromoler
µmhos/cm	micro mhos per centimeter
mg	milligram
MIBIC	methyl isobutylketone
ml	milliliter
msl	mean sea level
MRL	minimum risk level
NAICP	Navy Assessment and Control of Installation Pollutants
NEESA	Naval Energy and Environmental Support Activity
NCP	National Contingency Plan



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NOAA	National Oceanic and Atmospheric Association
NOAEL	no observed adverse effect level
NSC	Naval Supply Center
PAH	polycyclic or polynuclear aromatic hydrocarbons
PCE	tetrachloroethane
PCBs	polychlorinated biphenyls
PP	priority pollutants
PPA	Petroleum Products Area
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PVC	polyvinyl chloride
QADSY	Q Area Drum Storage Yard
RA	Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RBC	risk-based concentration
RI/FS	Remedial Investigation/Feasibility Study
RfD	reference dose
RGOs	remedial goal objectives
RME	reasonable maximum exposure
SARA	Superfund Amendments and Reauthorization Act
sf	square feet
SVOC	semi-volatile organic compound
SWMU	solid waste management unit
S <sub>y</sub>	specific yield
T	transmissivity
TA	Transit Area
TAL	target analyte list
TCA	trichloroethane
TCE	trichloroethene
TCL	target compound list

TCLP	toxic characteristic leachate procedure
TDS	total dissolved solids
TEFs	toxicity equivalence factors
TOV	total organic vapor
TOX	total organic halogens
TPH	total petroleum hydrocarbon
TTLC	total threshold limit concentration
UCL <sub>95</sub>	95% upper confidence level
UR	unit risk
USCS	United States Classification System
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VDEQ	Virginia Department of Environmental Quality
VOC	volatile organic compound
WoE	weight-of-evidence
yr	year

## RI EXECUTIVE SUMMARY

Environmental Science & Engineering, Inc. (ESE) performed an investigation of the Q Area Drum Storage Yard (QADSY) as the initial phase of a Remedial Investigation/ Feasibility Study (RI/FS) under contract number N62470-D-90-7661 for the United States Navy, Atlantic Division, Naval Facilities Engineering Command (LANTNAVFACENGCOM). The purpose of the RI was to characterize the geologic setting of the site, identify the nature and extent of contamination, and identify the impact on or threat to human health and the environment.

### Background

The QADSY is located on the Sewells Point Naval Complex on the Norfolk Naval Base (Figure ES-1). It was created by a fill operation in the early 1950s and was used as a disposal area for dredged materials from Willoughby Bay. The site is currently a relatively flat fenced area, paved with crush-and-run gravel, and bounded by asphalt parking lots to the north and west.

The QADSY has been in use since the 1950s. Tens of thousands of drums containing solvents, oils, lubricants, paint thinners, pesticides, and acids have been stored there since that time. Throughout its history, the northern portion of the site was used to store damaged and leaking drums.

Since 1982, a number of investigations and reports have been conducted and prepared under various Navy programs to assess the nature and extent of contamination and contaminant migration.

### Scope of the Remedial Investigation

RI activities began in August 1990 and continued through May 1995. The RI included surface and subsurface soil, groundwater, sediment, and surface water investigations.

Initially, surface soil samples were collected at two intervals from 36 borings within and adjacent to the QADSY (ES-2). A total of 48 samples from 24 of the borings were analyzed for volatile organic compounds (VOCs) and total petroleum hydrocarbon (TPH), 41 for toxicity characteristics leaching procedures (TCLP) metals, 18 for semi-volatile organic compound (SVOC) extractables and pH, and 5 for total organic halogens (TOX). Samples for the remaining 12 borings were analyzed for full toxic characteristic leachate procedure (TCLP) parameters.

Based on the findings of the initial sampling effort, 16 soil samples were collected for analysis from eight power-drilled auger borings in December 1992. Subsurface soil samples

were collected from two intervals (3 to 5 feet and 5 to 7 feet) to determine the vertical and lateral extent of TPH contamination in the onsite soils.

Additional sampling effort included collecting 19 subsurface soil samples in May 1995, 15 of which were used to determine the lateral extent of TPH contamination. The four remaining samples were analyzed for VOCs, SVOCs, pesticides/polychlorinated biphenyls (PCBs), inorganic compounds (IOCs), and cyanide (Figure ES-2).

Ten shallow wells and eight deep wells were installed within and adjacent to the QADSY (Figure ES-3). The deep wells were installed to test the deeper aquifer zone. No confining layer was encountered between the shallow wells and the base of the deep wells, indicating that the shallow and deep wells are hydraulically connected.

A total of 16 monitor wells were constructed of 2-inch inner diameter (ID), flush joint, threaded polyvinyl chloride (PVC) well screen, riser, and casing. The other two wells (SW-3 and DW-1) were constructed of 6-inch ID, flush joint, threaded PVC well screen, riser, and casing.

Each shallow well was sampled at the top of the screen (10 to 15 feet from topographic surface) and near the base of the well screen (25 feet) for VOCs, TPH, and pH. Samples for IOC analysis were also taken from the 25-foot interval in SW-1, SW-2, SW-3, SW-4, SW-5, and SW-8 in October 1990 and the three existing wells GW-1, GW-3, and GW-4 in January 1991. DW-1 and DW-2 were sampled from the 35- to 40-foot interval for VOCs and pH in October 1990. Additional well sampling was performed with the same procedures as above. Samples for IOCs were collected in October 1992 from the shallow and deep intervals in SW-2, SW-5, SW-8, DW-1, and DW-2. Samples for trichloroethene (TCE), tetrachloroethane (PCE), and 1,2-dichloroethene (DCA) were collected in January 1993 from the shallow and deep intervals at SW-9, SW-10, and DW-8 and the deep intervals at DW-3 through DW-7. Baker Environmental collected groundwater samples from DW-3 through DW-8, SW-9, and SW-10 for VOCs, SVOCs, pesticides/PCBs, IOCs, and cyanide.

A total of 66 groundwater samples were collected from 18 locations using the hydropunch sampling technique in December 1992 (Figure ES-3). The samples were analyzed for TCE, PCE, and DCA using a Photovac field gas chromatograph. At least two hydropunch samples were collected at each location. Groundwater samples were collected at 10-foot intervals beginning at 15 feet below surface. Hydropunch samples were collected until contamination was below detection limits or two consecutive samples were at or below 5 micrograms per liter ( $\mu\text{g/l}$ ) for all compounds.

Sediment soil samples were collected to determine if surface contamination travels directly into the storm drain that eventually reaches the Elizabeth River. Two sediment samples were collected in the storm drain south of monitor well SW-4 (SD-1) and north of the trailer (SD-2) (Figure ES-2). The samples collected from the storm drains were analyzed for full TCLP parameters.

One background surface water sample was collected from the Elizabeth River between Piers 10 and 11 west of the QADSY in October 1992 and analyzed for IOCs.

Tidal influences were considered for the hydraulic calculations due to the proximity of the site to Willoughby Bay. Two wells (SW-6 and SW-8) were monitored to calculate tidal influence on water table fluctuation. "True" drawdown in the observation wells was calculated by compensating for tidal fluctuation.

In-situ rising and falling head permeabilities (slug) tests were carried out on eight wells to evaluate the hydraulic conductivity of the aquifer. In addition, a 72-hour aquifer drawdown test was performed to assess additional aquifer parameters such as transmissivity and storativity. A groundwater model was performed using data from the slug tests and pump test.

## Geologic and Hydrogeologic Assessment Results

The QADSY is located within the Atlantic Coastal Plain Physiographic Province. Two major geologic formations underlie the site. The Lynnhaven Member of the Tabb Formation is characterized by gravels, sands, silts, and clays with some shell fragments; it is heterogeneous and approximately 20 feet thick. The Yorktown Formation is characterized by gravels and thick shell beds and ranges from 300 to 400 feet thick. A confining layer does not exist between the two formations at the site; it appears to be eroded from meandering of the Elizabeth River.

Specifically, the site is underlain by yellow-brown, gray, and black silty sands with shell fragments. (The uppermost deposits are most likely representative of the fill operation used to create the site, rather than the Tabb Formation lithology.) Brown to black clay lenses are encountered in some of the borings 20 to 30 feet below surface.

During the RI, only one aquifer was penetrated at the QADSY: an unconfined water table aquifer situated within the fill deposits and deposits of the Tabb and Yorktown formations. Groundwater flows west across the site, and the hydraulic gradient is shallow, averaging 0.0021 foot/foot (ft/ft). Aquifer recharge is by infiltration in areas where pavement is absent, and possibly by regional flow within the base. The aquifer tests indicated that the water table aquifer has an average hydraulic conductivity of 11 feet per day (ft/day), a transmissivity of 1362 square feet per day (sf/day), and a specific yield of 0.0317.

The City of Norfolk prohibits the use of the Columbia (unconfined) aquifer for potable water for private or public supplies. Potable water is supplied by the City of Norfolk. The Yorktown aquifer is adjacent to the Elizabeth River and Willoughby Bay and is not potable because it is brackish.

## Aquifer Testing and Groundwater Modeling

### Aquifer Pump Test Results

A 72-hour aquifer pump test was conducted between 29 January and 1 February 1991. Monitor well SW-3 was pumped at a constant rate of 5.2 gallons per minute (gpm), generating a constant drawdown of approximately 10 feet. The water levels were recorded in six monitor wells (SW-1, SW-2, SW-4, SW-5, SW-6, and SW-8) and the recovery well (SW-3) for the duration of the pump test.

A large tidal influence was observed at the site, and fluctuation in each well was not constant: a mean value for the water level had to be calculated from the water level graphs.

The pump test provided useful data concerning hydraulic conditions. The data were input into AQTESOLV® (a hydraulic software package for time versus drawdown in confined and unconfined aquifers, developed by Geraghty & Miller, Inc.) under the assumption that an unconfined aquifer is present beneath the QADSY. The results showed a higher-than-expected transmissivity (T) and a hydraulic conductivity (K). The specific yield ( $S_y$ ), 0.0317, also does not appear to be representative of the aquifer. Because K and T do not appear to accurately represent the aquifer, ESE conducted slug tests on wells SW-1, SW-2, and SW-4 through SW-8 to further evaluate T and K values to be input into the groundwater model.

Slug tests performed on 20 March 1991 were used to determine aquifer hydraulic conductivity and transmissivity. Average T and K data calculated from the slug test were 1362 sf/day and 11 ft/day, respectively. Continuous water level data were collected at DW-1 and SW-1 between 9 December 1992 and 12 January 1993.

Additional, simultaneous water level data from the National Oceanic and Atmospheric Administration (NOAA) tide station at Sewells Point were obtained for comparison. Plotting the two water level signals indicates a distinct correlation. The results of the two data sets analyzed indicate that a maximum correlation occurs when the tide signal is advanced 50 minutes. This indicates that the peak groundwater potentiometric level occurs approximately 50 minutes after high tide.

Head differences were also calculated for the two data sets. The difference in elevation between Sewells Point tidal values and DW-1 was calculated. Positive values represent tidal elevations higher than groundwater elevations. A mean value of -1.9 feet resulted for the month of data, suggesting a net negative influence of the tide on the groundwater at the site and a net positive gradient toward the Elizabeth River and Willoughby Bay. The effect would be to allow dispersal of the local groundwater to the surrounding surface water. Gradient magnitudes depend on the proximity of the local water body and the phase of the tide. Assuming a minimum distance to Willoughby Bay of 900 feet to the southeast and the mean hydraulic head of 1.9 feet, the gradient is 0.0021.

An additional data set consisting of the tidal heights and a piezometer installed in the submarine sediments was collected from 13 to 22 January 1993. The potentiometric head difference of the surface water to the piezometer height was very low. It can be assumed, however, based on the seaward gradient and piezometer/river head difference, that the local groundwater is discharging into the surrounding surface waters.

## Groundwater Modeling Results

ESE used MODFLOW (McDonald and Harbaugh, 1988), a three-dimensional groundwater flow model, and INTERTRANS, a three-dimensional transport model, to determine if contaminants are entering the surface water body of Elizabeth River.

The area is bounded by the Elizabeth River on the west, Willoughby Bay on the east, and Bunker Hill Taxiway on the south. The flow system has been conceptually characterized as a two-layer system separated by a semiconfining layer. Model input included boundary conditions to represent the Elizabeth River, the bulkhead along the Elizabeth River, Willoughby Bay, and recharge to provide a water source for the model.

Site-specific aquifer parameters were calculated from a series of slug tests and an aquifer pump test. Aquifer parameters have also been established from regional information collected by the USGS (Hamilton, 1988). The site-specific and regional data were used as initial model input values for hydraulic conductivity and transmissivity.

Based on the calibration process, the hydraulic conductivity of layer 1 was set as a uniform value of 10.9 ft/day and the thickness was set at 50 feet. The use of 10.9 ft/day is reasonable as a value for hydraulic conductivity for both the Columbia and Yorktown aquifers from the slug test data and from regional information. The calibrated transmissivity of layer 2 was 548 sf/day. The leakance value between layers 1 and 2 was set at 0.055 per day.

A potentiometric surface for the modeled area was established from the previous groundwater investigations. The elevation of this surface ranged from approximately 2 feet above mean sea level (msl) in the vicinity of the QADSY to approximately 0.5 foot above msl near the Elizabeth River. Flow is generally to the northwest to the Elizabeth River and northeast to Willoughby Bay.

ESE has developed a three-dimensional particle tracking solute transport model (INTERTRANS) that uses the potentiometric "heads" calculated from MODFLOW and tracks particles for a specified period of time. The model determined if the contaminants migrating from the QADSY to the bulkhead along the Elizabeth River will discharge to the surface water (Elizabeth River).

The 40-year scenario from the INTERTRANS model indicated that particles will move horizontally downgradient to the northwest toward Pier 12 and the Elizabeth River bulkhead,

dispersing horizontally and vertically to layer 2. The particles will reach the bulkhead and migrate down and under the bulkhead to the west of the river.

### **Air Sparging/Soil Vapor Extraction Pilot Study**

Target Environmental Services conducted two air sparging/vapor extraction (AS/SVE) pilot studies in May 1995. The purpose of the AS/SVE was to test the feasibility and obtain design data such as soil permeability and radius of influence for an AS/SVE system. Soil gas and groundwater samples, dissolved oxygen measurements, and groundwater levels were collected before, during, and after the AS/SVE pilot tests to measure the effectiveness of a potential AS/SVE system.

Calculated air conductivities ranged from  $1.3 \times 10^{-6}$  to  $7.9 \times 10^{-8}$  cubic centimeters ( $\text{cm}^2$ ) at the two sites. Permeability values are in the range from  $10^{-6}$  to  $10^{-10} \text{ cm}^2$  to be hydraulically conductive for remediation by vapor extraction.

The radius of vacuum influence ranges from 21 to 74 feet. The variations in the radius in influence appear to be from underground utilities causing variations in the soil permeability. The radius of air sparging influence ranges from 20 to 30 feet using at depth between 35 and 40 feet. Increasing the injection flow could increase the radius of sparging influence and effects of VOCs removal. Groundwater sample data indicated a decrease of concentration levels.

The increase of dissolved oxygen and groundwater potentiometric levels also indicated that AS/SVE is a feasible remediation technique at the QADSY.

## **Contaminant Evaluation Results**

### **Soils**

The QADSY was divided into five separate parcels for the investigation (Figure ES-3).

Soil contamination at the site appears to be limited to VOCs and petroleum hydrocarbons. Some small-scale SVOC, pesticides/PCBs, and IOC contamination may also be present, but it is below applicable TCLP standards or EPA Region III risk-based concentrations.

VOC contamination is generally at a very low level; the most affected area in terms of frequency and concentration of compounds is the Hazardous Materials (HM) Area. One sample in the HM Area indicated 32,000 micrograms per kilogram ( $\mu\text{g/kg}$ ) of PCE; however, all other HM samples and samples from other areas at the site were below 1000  $\mu\text{g/kg}$  total VOCs, and the vast majority were below 100  $\mu\text{g/kg}$ .

TPH contamination is widespread across the Transit Area (TA), Petroleum Products (PPA) area, and HM area. TPH concentrations were detected in only one sample from the Truck and Equipment Storage Yard (EY) area. Concentrations ranged from 0 to 4400 parts per



million (ppm) across the site. A hydrocarbon that closely matches the referenced standard for compressor oil was the most common: lube oil, hydraulic jack oil, and motor oil were less frequently detected. More than 50 percent of the samples from the PPA, HM, and TA areas exceeded the 100 ppm Virginia Department of Environmental Quality (VDEQ) action levels, and 66 percent exceed the 50 ppm VDEQ guideline for disposal of the soil as clean fill.

Sampling was performed of the 3- to 5-foot interval and the 5- to 7-foot interval of the HM, PPA, and TA areas of highest TPH concentration to characterize the vertical extent of contamination. The results indicated low levels of contamination (between 16 and 47 ppm) at these depths from the HM area, below the VDEQ guidelines (50 ppm) for soil disposal as clean fill.

Two site areas (the northern PPA area and the TA) appear to have levels of metals that are marginally higher than levels found in the background samples and apparently non-contaminated samples from other site areas. None of the soil samples were above applicable federal standards using the TCLP extraction method. IOCs were below the RBCs.

## Groundwater

Analytical data suggest significant onsite and offsite groundwater VOC contamination and to a lesser extent, TPH and metals. The analytical data for VOCs in the TA and the results of the hydropunch survey in the Fleet Parking (FP) area show no discernable consistency; this may reflect past area use for loading and storage where no large, long-term sources were developed.

VOC impact was most severe in the shallow groundwater beneath the HM area and northern portion of the PPA area. Total VOC concentrations peaked in SW-2 (7800 µg/l) with contamination by PCE, TCE, 1,1,1-TCA, 1,2-DCE, 1,1-DCE, 1,1-DCA, carbon tetrachloride, and acetone. SW-1 (150 feet to the north) was similarly impacted with a total VOC concentration of 3446 µg/l. Shallow wells outside the QADSY (SW-9 and SW-10) exhibited only low PCE and TCE levels. Many of the same contaminants were observed in downgradient wells GW-1 and SW-6, but at lower levels.

Smaller contaminant plumes may have formed beneath the TA, as observed by total VOC concentrations in SW-4 and SW-5 (60 and 76 µg/l). No discernible plumes were visible, and the pattern likely reflects the use of the TA as an offloading and temporary storage area where no long-term sources developed.

Only very low VOC levels were observed in the deep wells (sample depths between 35 and 65 feet), indicating that the maximum depth of the contaminant plume may not be much greater than the intervals at which the samples were taken. TCE levels were observed at a maximum concentration at 35 feet below surface and at a maximum depth of 65 feet.

The hydropunch survey presented dispersion of high concentration readings throughout the site that suggest many sources of contamination. Two main TCE plumes were observed at 15, 55, and 65 feet from surface.

The highest TCE concentration was at 35 feet below surface at 1371  $\mu\text{g/l}$  (HP-15-35). PCE was detected at 15 and 25 feet below surface. PCE was found below the detection limits for depths from 35 feet from surface.

TPH detected in the water samples did not match any of the reference standards or "fingerprints" used in the analysis: biodegradation may have altered the makeup of the hydrocarbons within the groundwater. Concentrations ranged from 1 ppm to between 1 and 5 ppm, but only six wells were impacted. Interestingly, none of the wells within the PPA area was affected. The VDEQ standard for TPH in groundwater is 1 ppm.

IOC contamination appeared to be evident during the initial sampling effort beneath the TA and northern part of the PPA areas. VDEQ groundwater standards were exceeded for cadmium, chromium, and zinc in SW-2, SW-4, SW-5, and GW-4; for arsenic in SW-2 and SW-5; and for lead in SW-2, SW-4, and SW-5. SW-5 also exceeded the standards for mercury during the second sampling event. DW-3, DW-5, DW-6, SW-9, and SW-10 also exceeded the VDEQ groundwater standard for cadmium during the last sampling event.

## **Sediments**

Sediment samples were taken on 21 January 1993 from storm drainage conduits in the QADSY. When analytical results were compared to the US Environmental Protection Agency, Region V guidelines, the sediments are considered moderately polluted for arsenic, barium, chromium, and manganese. The sediments are considered heavily polluted for the elements barium, copper, iron, lead, and zinc. The sediments do not exceed typical concentrations in soils in the eastern United States (Shacklett and Boerngen, 1984), and Federal Register Proposed Rules 20 May 1992 for concentration-based exemption criteria for hazardous waste listing, and Federal Register 27 July 1990 for corrective action criteria.

TCLP pesticide/polychlorinated biphenols (PCBs) analysis revealed concentrations of the pesticides chlordane and DDT homologues (DDE, DDD). The presence of these pesticides was not detected previously in the TCLP analysis run on soil borings from the QADSY, suggesting that these contaminants may have originated in some other area of the base.

Both sediment samples were analyzed for TPH as gasoline and as diesel. TPH as diesel was detected at a level of 299 milligram/kilogram (mg/kg) in SD-1 and 58.3 mg/kg in SD-2. The sample from SD-1 exceeds the VDEQ standard for disposal.

## **Surface Water**

One surface water sample was collected from the Elizabeth River between Piers 10 and 11 west of the QADSY in October 1992. The surface water sample was analyzed for IOCs.

Only antimony was detected in the filtered and unfiltered samples at a concentration over 300 µg/l. No standards currently exist for antimony in surface water.

## **Risk Assessment**

The Risk Assessment (RA) was generated in accordance with EPA region-wide and Region III guidance to assess the potential current and future human and ecological health risks associated with potential onsite exposures at the QADSY, assuming no remedial action is implemented at the site. The risk results are then used to develop remedial goal objectives (RGOs), goals which remedial alternatives strive to achieve considering other factors such as feasibility and achievability.

The RA is comprised of the following six primary components:

1. Identification of chemicals of potential concern (COPCs)
2. Environmental fate/transport analysis
3. Exposure assessment
4. Toxicity assessment
5. Risk characterization
6. Development of RGOs

### **Identification of COPCs**

This section identifies the primary site-related COPCs at the QADSY. Based on past site operations and disposal activities at the site, the COPCs evaluated in the Human RA (HRA) and Ecological RA (ERA) include a subset of IOC, VOCs, and SVOCs. The data used in the RA are taken from ESE and Baker Environmental sampling events (1990-1995) and sampling events from a previous contractor (Malcolm Pirnie, 1983-1986). The most recent and/or reliable data are used in the calculation of the exposure concentrations for the RA. The number of chemicals to be evaluated in the RAs was reduced using 1) EPA Region III methodology for risk-based concentration screening, 2) comparison of site and background soil concentrations, and 3) a screening for nutritionally essential chemicals. The specific COPCs evaluated in the HRA and ERA are presented in Table ES-1.

In addition, TPH was detected at the site. Although this group of chemicals is useful for determining the extent of petroleum-based contamination, a quantitative risk evaluation is not performed as TPH represents a large group of chemicals, typically composed of long, straight-chain hydrocarbons of relatively low toxicity. However, to provide a conservative risk evaluation, the carcinogenic PAHs were used as a surrogate to evaluate TPH.

### **Environmental Fate/Transport Analysis**

Chemical fate/transport analysis is an important aspect of the exposure assessment, as this analysis describes the mobility of chemicals in the environment and the pathways by which these chemicals may migrate to a potential exposure area. This section summarizes the physical and chemical properties of the COPCs, the environmental fate processes potentially acting on the COPCs, and the contaminant migration pathways potentially associated with the

COPCs. Although concentrations of site contaminants in soil and groundwater may be reduced by microbial degradation, volatilization, and photolysis, the environmental models used at this site indicate that the potential does exist for site chemicals to volatilize into site structures and migrate to surface water of the Elizabeth River.

### **Exposure Assessment**

The exposure assessment is the cornerstone of the risk assessment process, as this step identifies significant human and ecological exposure pathways and population(s) based on the environmental fate/transport analysis; determines the exposure concentrations to potential receptors; and estimates the magnitude, duration, and frequency of exposure for each receptor (or receptor group). The primary exposure pathways evaluated in the HRA and ERA are as follows:

#### Human Exposure Pathways

Current Worker -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

Future Worker -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

Future Residential -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

#### Ecological Exposure Pathways

Terrestrial -- ingestion of contaminated fish by great blue heron.

Aquatic -- exposure to surrounding surface water and sediment by aquatic and benthic organisms.

Groundwater consumption is an incomplete human exposure pathway as the water beneath the QADSY site is not potable due to the high salinity of the water. Thus, this pathway, under the guidance of State and Federal regulatory agencies, is not further evaluated in the RA. However, due to the presence of VOCs in groundwater beneath the site, inhalation of VOCs volatilized from groundwater into indoor air is evaluated.

Due to the lack of exposed soil (the site is gravel-covered and scheduled to be paved) and habitat suitable for food and shelter, exposure of terrestrial mammals to soil does not provide for any completed exposure pathways and was not quantified in the ERA.

### **Toxicity Assessment**

The primary purpose of the toxicity assessment is to summarize the toxicological properties of the COPCs and identify concentration levels that are not expected to produce adverse effects. A literature and database search was conducted to obtain the toxicological properties of the COPCs, including pharmacokinetics, metabolism, acute and chronic toxicity, carcinogenic and noncarcinogenic effects on human receptors, wildlife, and aquatic species.

The primary sources of toxicological data were from EPA-verified references. When an appropriate toxicological constant was not identified, current literature was reviewed to find

appropriate toxicological data, which were used to calculate dose-response values using the methodologies outlined in EPA guidance documents.

### Risk Characterization

The site-specific human carcinogenic and noncarcinogenic risk estimates are determined using the exposure concentrations and factors presented in the exposure assessment along with the dose-response information developed in the toxicity assessment. The potential carcinogenic risks are compared with the EPA target cumulative risk range of  $1 \times 10^{-6}$  (1 in 1,000,000) to  $1 \times 10^{-4}$  (1 in 10,000) [NCP, 40 Code of Federal Regulations (CFR) 300, 430:62].

When a cumulative carcinogenic risk (risk associated with exposure to a mixture of chemicals) to an individual receptor under the assumed exposure conditions at a Superfund site exceeds  $10^{-4}$ , CERCLA generally requires remedial action at the site (EPA, 1991d). If the cumulative risk is less than  $10^{-4}$ , action generally is not required but may be warranted if a chemical-specific standard that is risk based [e.g., the maximum contaminant level (MCL) or an ambient water quality criterion (AWQC)] is violated. A risk-based remedial decision could be superseded by the presence of noncarcinogenic impact or environmental impact at the site as indicated by a hazard index (HI) greater the 1 for human noncarcinogenic exposures or an exceedance of an ecotoxicity quotient (EQ) of 1 for aquatic or terrestrial exposures.

### Human Risk Characterization Results

The results of the HRA indicate that the following scenarios exceed either a cumulative risk of  $10^{-4}$  or an HI of 1:

Exposure Scenario	Medium	Exceedance	COCs
Future Worker	Indoor air	Risk > $1 \times 10^{-4}$	carbon tetrachloride, chloroform, 1,1-dichloroethene, tetrachloroethene, trichloroethene, and vinyl chloride
		HI > 1	carbon tetrachloride
Future Residential (Lifetime)	Indoor air	Risk > $1 \times 10^{-4}$	carbon tetrachloride, chloroform, 1,1-dichloroethane, 1,1-dichloroethene, tetrachloroethene, 1,1,1-trichloroethane, trichloroethene, vinyl chloride

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(Child)	Indoor air	HI > 1	carbon tetrachloride, 1,1-dichloroethane, 1,1,1-trichloroethane
	Soil	HI > 1	thallium
(Adult)	Indoor Air	HI > 1	carbon tetrachloride

### Ecological Risk Characterization Results

Terrestrial--The EQs associated with exposure of great blue heron to site contaminants due to ingestion of fish are all less than 1, suggesting that there is low potential for adverse effects to the great blue heron due to site-related chemicals in fish caught near the site.

Aquatic--The EQs for water- and sediment-dwelling aquatic organisms at QADSY are all less than 1, indicating that there is low potential for adverse effects to these aquatic organisms.

### RGOs

The Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that remedial actions attain a degree of contaminant cleanup that ensures protection of public health and the environment. Thus, the risk characterization results are used to identify whether site COPCs need to be reduced to acceptable health-based levels. The acceptable health-based levels are referred to as RGOs, which are chemical-specific concentration goals for individual chemicals for specific medium and reasonable land use combinations.

Based on the results of the risk characterization, future worker exposure to indoor air and future residential exposure to indoor air and soil resulted in a cumulative risk exceeding  $10^{-4}$  and/or an HI exceeding 1. However, to provide a complete site analysis, RGOs are developed for all chemicals contributing an individual risk of at least  $10^{-6}$  to a total of greater than  $10^{-4}$  or on HI of at least 0.1 to a total HI of greater than 1.

The site is located in an industrial area, and is intended to remain as such. In addition, the site is covered with six to eight inches of gravel and is scheduled to be paved in the near future, and the remaining site vicinity is paved. Therefore, although evaluated, exposure to soil is unlikely under current and future site use plans, and RGOs for soil are not calculated. In addition, while an assessment of residential exposure is performed in the HRA, according to discussions with regulatory agencies responsible for the site, it is done only to provide perspective on worst-case plausible exposures and will not be used as a basis for remedial decisions. In summary, RGOs are derived for the following chemicals to provide risk managers with the maximum risk-related media level options on which to develop remediation aspects of the Feasibility Study (FS):

Medium	Scenario	COCs
Groundwater	Future Worker	Carbon tetrachloride, chloroform, 1,1-dichloroethene, tetrachloroethene, trichloroethene, and vinyl chloride
	Future Resident	Carbon tetrachloride, chloroform, 1,1-dichloroethane, 1,1-dichloroethene, tetrachloroethene, 1,1,1-trichloroethane, trichloroethene, and vinyl chloride

Table ES-1. COPCs Evaluated in the HRA and ERA (Page 1 of 2)

COPC	HRA	ERA
<u>IOCs</u>		
Antimony	--	GW,SE,SW
Arsenic	SO	GW,SE,SO,SW
Barium	--	GW,SE,SO,SW
Beryllium	--	GW,SE,SW
Cadmium	--	GW,SE,SW
Chromium	--	GW,SE,SW
Copper	--	GW,SE,SO,SW
Iron	--	GW,SE,SO,SW
Lead	--	GW,SE,SO,SW
Manganese	--	GW,SE,SW
Mercury	--	GW,SE,SW
Nickel	--	GW,SE,SW
Selenium	--	GW,SE,SW
Silver	--	GW,SE,SW
Thallium	SO	GW,SE,SO,SW
Vanadium	--	GW,SE,SO,SW
Zinc	--	GW,SE,SO,SW
<u>Munitions / Nitroaromatic Chemicals</u>		
2,4-Dinitrotoluene	SO	SO
N-Nitrosodi-N-propylamine	SO	SO
<u>PAHs</u>		
Acenaphthene	--	SO
Benz(a)anthracene	SO	SO
Benzo(a)pyrene	SO	SO
Benzo(b)fluoranthene	SO	SO
Benzo(ghi)perylene	--	SO
Benzo(k)fluoranthene	SO	SO
Chrysene	SO	SO
Fluoranthene	--	SO
Indeno(1,2,3-cd)pyrene	SO	SO
Phenanthrene	--	SO
Pyrene	--	SO
<u>Pesticides</u>		
Aldrin	SO	SO
BHC, beta-	--	SO
BHC, delta-	--	SO
Chlordane, alpha-	SO	SO
Chlordane, gamma-	SO	SO
DDD, p,p'-	--	SO
DDE, p,p'-	--	SO
DDT, p,p'-	--	SO
Endosulfan sulfate	--	SO
Lindane	SO	SO

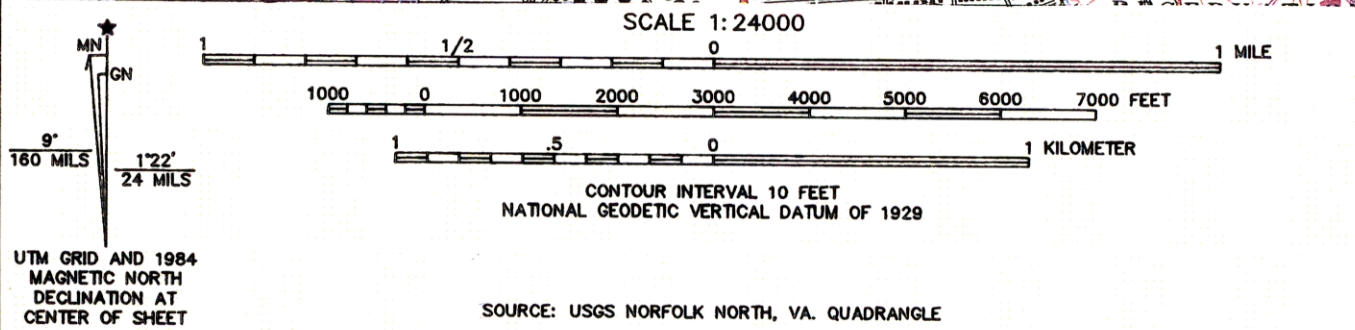
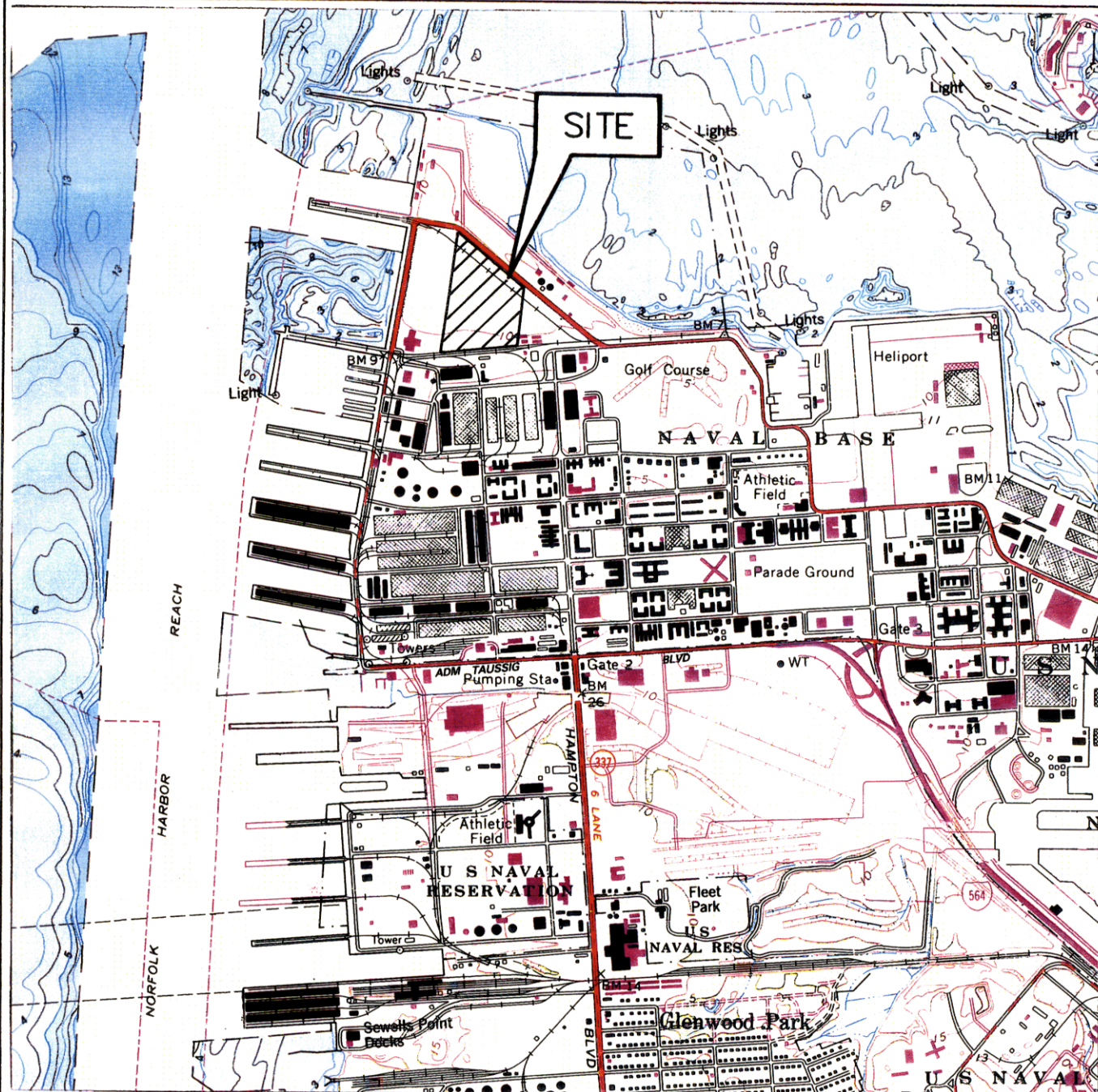


Table ES-1. COPCs Evaluated in the HRA and ERA (Page 2 of 2)

COPC	HRA	ERA
<u>SVOCs, misc.</u>		
Bis(2-ethylhexyl) phthalate	—	GW,SO,SW
Butylbenzyl phthalate	—	SO
Di-n-butyl phthalate	—	SO
Dichlorobenzene, 1,4-	—	SO
Dimethylphenol, 2,4-	—	SO
Phenol	—	SO
Trichlorobenzene, 1,2,4-	—	SO
<u>VOCs</u>		
Acetone	GW,IA	GW,SO,SW
Benzene	—	SO
Bromodichloromethane	GW,IA	GW,SW
Carbon tetrachloride	GW,IA	GW,SW
Chloroform	GW,IA	GW,SW
Dichloroethane, 1,1-	GW,IA	GW,SW
Dichloroethene, 1,1-	GW,IA	GW,SO,SW
Dichloroethene, 1,2-	GW,IA	GW,SO,SW
Methylene chloride	GW,IA	GW,SO,SW
Tetrachloroethene	GW,IA	GW,SO,SW
Toluene	—	GW,SO,SW
Trichloroethane, 1,1,1-	GW,IA	GW,SO,SW
Trichloroethene	GW,IA	GW,SW
Vinyl chloride	GW,IA	GW,SW
Xylenes	—	SO

Note: GW = groundwater  
 IA = indoor air  
 SE = sediment  
 SO = soil  
 SW = surface water  
 — = not a COPC in this medium

Source: ESE



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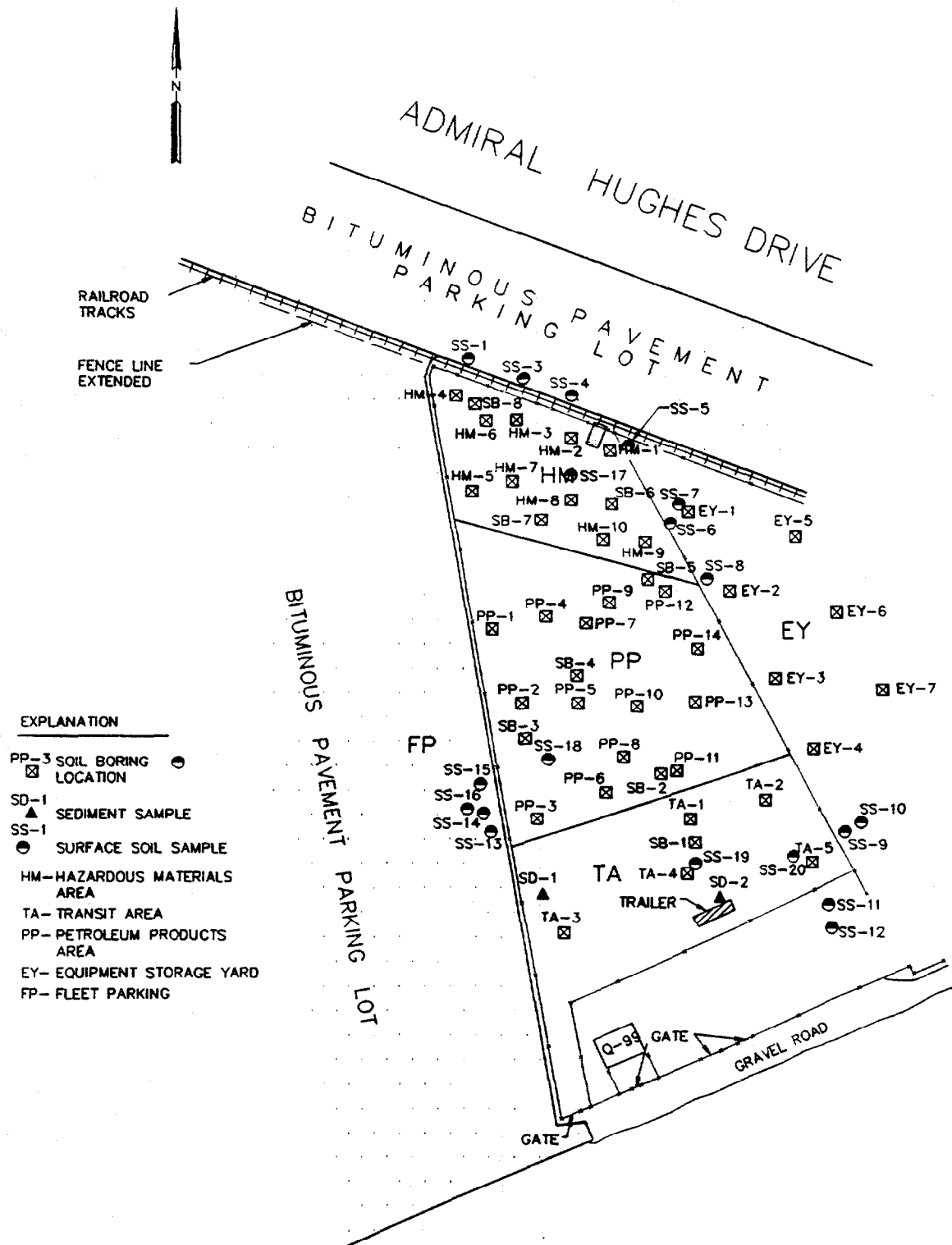
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Naval Base - Norfolk, Virginia

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FIGURE  
ES-1

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MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

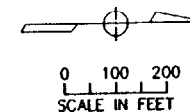
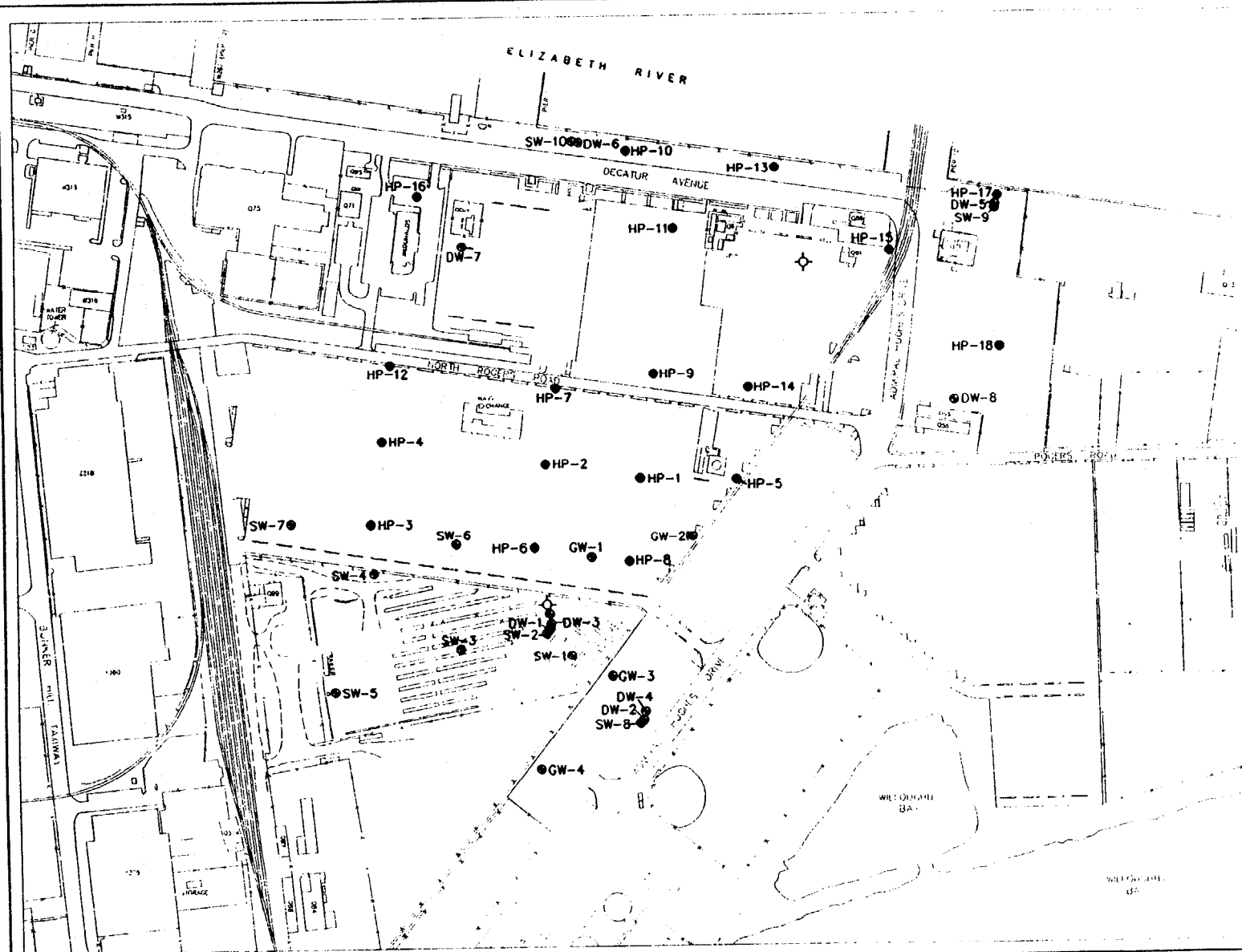
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# LEGEND

- HYDROPUNCH LOCATION
- MONITOR WELL LOCATION
- ◇ AIR SPARGING/  
SOIL VAPOR EXTRACTION  
PILOT STUDY LOCATION



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TITLE

MONITOR WELL HYDROPUNCH, AND  
AS/SVE PILOT STUDY LOCATIONS  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE

ES-3

## **1.0 INTRODUCTION**

### **1.1 Purpose of Report**

The Superfund Amendments and Reauthorization Act (SARA) of 1986 required each federal facility listed on the Federal Agency Hazardous Waste Compliance Docket to follow the rules, regulations, guidelines, and criteria established by the Environmental Protection Agency (EPA) for the Superfund Program. The Remedial Investigation/Feasibility Study (RI/FS) represents the methodology that the Superfund program has established for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites and for evaluating potential remedial options. The purpose of this draft RI report is to build on the data collected in previous investigations and to develop an environmental risk assessment (RA) to determine if the site is releasing hazardous substances, pollutants, or contaminants into the environment that may require a removal action.

### **1.2 Site Background**

The QADSY is located on the Norfolk Naval Base and is part of the Sewells Point Naval Complex (Figure 1-1). It is located in the northwest corner of the complex, within 1200 feet of both the Elizabeth River (to the west) and Willoughby Bay (to the northeast).

#### **1.2.1 Site Description**

The QADSY was created by a fill operation in the early 1950s and was used as a disposal area for dredged materials excavated from the James River, Elizabeth River, and/or Willoughby Bay. The site is a relatively flat, open earthen yard covered by crush-and-run gravel; it is bounded on the north and west by asphalt-paved parking lots.

The dredged material may have the potential to contain elevated levels of contamination. "Background" areas for the site will have elevated contaminant levels if established from the dredged fill area.

#### **1.2.2 Site History**

The QADSY has been in use since its creation in the 1950s, and tens of thousands of drums have been stored at the site since that time (LANTNAVFACENGCOM, 1988). A variety of materials were stored in 55-gallon steel drums, including petroleum products (such as oil lubricants), various organic solvents, paint thinners, and some pesticides, formaldehyde, and



acids. Throughout the site's history, the northern portion of the yard was used to store damaged and leaking drums. The site has not been used since 1987.

During a site visit in June 1990, drum storage occurred in three general areas:

- Hazardous Materials (HM) Area
- Petroleum Products Area (PPA)
- Transit Area (TA)

These areas are described in detail in Section 3.2. Various products were stored onsite at the time of the site visit, including chlorinated solvents, hydraulic fluid, and lube oil.

### 1.2.3 Previous Investigations

The Navy Assessment and Control of Installation Pollutants (NACIP) Program was promulgated in 1980 to systematically identify, assess, and control contamination from past hazardous material operations that pose a potential threat to human health or the environment. The Initial Assessment Study (IAS) was conducted as the first phase of the NACIP Program to collect and evaluate evidence indicating the existence of pollutants that may have contaminated sites at the Sewells Point Naval Complex and that may pose an imminent health hazard to people located on or off the installation. The IAS was conducted prior to the enactment of SARA, but is considered to fulfill the requirement for each federal facility listed on the Federal Agency Hazardous Waste Compliance Docket to perform a Preliminary Assessment.

The onsite phase of the IAS was conducted in May 1982, at which time the QADSY was identified as one of 18 potentially contaminated sites. During the IAS survey, evidence of considerable liquid leakage and spillage was noted throughout the site (Figure 1-2). In particular, the northern portion of the site was used to store damaged and leaking drums. Recommendations were made to install and sample (quarterly) three monitor wells; recommended analytes included oil and grease, volatile organic compounds (VOCs), pesticides, and polychlorinated biphenyls (PCBs). The IAS report (NEESA, February 1983) suggested that the wells be located downgradient of the QADSY, with specific attention to the leaking drum area.

Subsequent to the IAS, the NACIP Program was redesigned as the Installation Restoration Program (IRP). The terminology and structure of the IRP were changed to conform to that of SARA. The RI Interim Report (LANTNAVFACENGCOM, March 1988) was designed to verify the existence of contamination, satisfying the site investigation requirement of SARA, but it does not meet the full requirements of an RI. The objective was to incorporate the RI Interim Report into a completed RI/FS document at a later date.

The initial site investigation for the interim RI was conducted in November and December of 1983. Four monitor wells were installed at that time, and 12 soil samples were analyzed from four hand borings, S-05 through S-08 (Figure 1-3). A second round of groundwater sampling was performed in August 1984. Groundwater samples from the existing wells and 21 soil samples from seven locations (S-09 through S-15) were analyzed as part of the third round of sampling, performed in April 1986. The Navy analyzed eight soil samples in April 1986 following the groundwater event (Figure 1-4); this effort resulted in plans to remove the most contaminated soil as part of a 1989 military construction project. Finally, a fourth round of groundwater sampling occurred in June 1986. Complete Interim RI analytical results are included as Appendix A.

Soil sampling results indicated elevated levels of trans 1,2-dichloroethene (trans 1,2-DCE) and trichloroethene (TCE), particularly in the leaking drum storage area in the northern portion of the QADSY (Table 1-1). Boring S-06 (in the vicinity of the leaking drums) contained 1100 to 7000 micrograms per kilogram ( $\mu\text{g}/\text{kg}$ ) of trans 1,2-DCE and 16 to 1100  $\mu\text{g}/\text{kg}$  of TCE; concentrations of both diminished with depth. In addition, concentrations of phenol (3400 and 2200  $\mu\text{g}/\text{kg}$ ) and one semi-volatile organic compound (SVOC), phenanthrene (380  $\mu\text{g}/\text{kg}$ ), were detected in boring S-06 (Table 1-1). Phenol concentrations diminished with depth and were actually below the method detection limit (BDL) in the deepest (2- to 3-foot) sample. Conversely, phenanthrene was only detected in the deepest sample.

Seven inorganic compounds (IOCs) were detected in the soil adjacent to and outside of the leaking drum storage area; specifically, in samples S-05 and S-08 at the 0- to 1-foot depth only (Table 1-1). Three pesticides were detected in samples from boring S-07 at various depths.

Several IOCs were identified in soil samples collected from borings S-05, S-06, S-07, and S-08; however, the RI Interim Report only considered the arsenic concentrations elevated. Six samples from various locations and depths indicated that the soil was heavily polluted with arsenic, according to EPA Region V guidelines (one of the only sources available at the time for soil concentration criteria). In addition, five samples indicated the soil was moderately polluted, according to EPA Region V guidelines.

Oil and grease concentrations were elevated in all eight soil samples collected by the Navy in April 1986 (Table 1-1). Concentrations ranged from 4120 to 54,100 milligrams per kilogram ( $\text{mg}/\text{kg}$ ). According to the EPA Region V guidelines, the soil was considered to be heavily polluted.

Groundwater sampling during the interim RI indicated significant concentrations of organic constituents in the groundwater below the leaking drum storage area; specifically, monitor well GW-01 (Table 1-2). No significant organic concentrations were present in wells GW-02, GW-03, and GW-04, all hydrogeologically upgradient of the site. In groundwater samples from GW-01, trans 1,2-DCE ranged from 5600 to 9000 micrograms per liter ( $\mu\text{g}/\text{l}$ ) during the three sampling events; TCE ranged from 1000 to 6000  $\mu\text{g}/\text{l}$ ; 1,1,2,2-tetra-chloroethene (PCE)

ranged from 12 to 19 µg/l during two events (it was detected below the detection limit of 125 µg/l during the third event). In all cases, organic concentrations decreased from the initial sampling event to the third event. Trans 1,2-DCE and TCE were found in the soils in the vicinity of GW-01, suggesting that contaminants were leaching from the soil into the groundwater. Other organic contaminants detected in soil samples were not detected in the groundwater, including phenol, SVOCs, and pesticides.

Groundwater contaminant concentrations in the interim RI were compared to EPA Drinking Water Standards, EPA Water Quality Criteria, and Virginia Department of Environmental Quality (VDEQ) Groundwater Standards (Table 1-2). The EPA Drinking Water Standards were exceeded by vinyl chloride, DCE, TCE, and PCE concentrations; none of the EPA Water Quality Criteria for toxicity to aquatic life were exceeded. The VDEQ had no applicable standards for organic constituents.

IOCs were detected in all four wells; arsenic, chromium, and zinc were above the VDEQ Groundwater Standards in all wells (Table 1-2). Cadmium and lead were detected in three out of the four wells (GW-01, GW-02, and GW-03), and mercury was detected in three wells (GW-02, GW-03, and GW-04). The RI Interim Report considered these concentrations to be artificially high because the groundwater samples were unfiltered. Additionally, the IOCs contamination was not considered significant because groundwater is not used as a potable or non-potable source in the area. Arsenic was the only IOC contaminant that appeared to have migrated from the soil into the groundwater, having been detected in both media.

Oil and grease concentrations (40 to 110 milligrams per liter (mg/l)) were detected in all four wells during the first sampling round (Table 1-2). However, subsequent rounds indicated oil and grease concentrations below the detection limit of 2 mg/l in all wells except GW-04. Concentrations fluctuated from 7 to 610 mg/l in GW-04 during the three sampling events. Oil and grease concentrations in groundwater were not compared to any standards or guidelines in the RI Interim Report.

The RI Interim Report concluded that the source of the contaminants at the QADSY was the leaking and damaged containers, and that organics were leaching from the soil into the groundwater in that area. The report suggested that the soil may have been absorbing some of the VOCs, but not the IOCs. The need for downgradient wells was discussed, and recommendations included installing and sampling three additional nested wells. The report also recommended that additional soil samples be collected and analyzed for metals, extraction procedure toxicity (EP TOX) characteristics, total petroleum hydrocarbon (TPH), and ignitability. Additional suggestions included capping the entire QADSY, if it is determined to be nonhazardous, and containing the damaged and leaking drums.

Following the interim RI, the Navy excavated 750 cubic yards of soil in 1987, as shown in Figure 1-5 (LANTNAVFACENGCOM Memoranda, 1987). That portion of the QADSY is now paved and used for fleet parking. The contaminated soil was properly disposed of at a



permitted sanitary landfill operated by the Southeastern Public Service Authority in Suffolk, Virginia.

### **1.3 Report Organization**

The remainder of the draft RI report focuses on the present conditions at the QADSY and serves as documentation of data collection and analysis in support of the FS. Section 2.0 outlines the field activities associated with the QADSY investigation, and Section 3.0 summarizes the physical characteristics of the site determined through the field activities. Section 4.0 presents hydrogeological tests and groundwater models. Sections 5.0 and 6.0 present the results of the site characterization and the contaminant fate and transport, respectively. The baseline risk assessment is included in Section 7.0, and Section 8.0 summarizes the RI.

**Table 1-1**  
**Summary of Interim RI Soil Analytical Results**

Analyte (µg/kg)	S-05	S-06	S-07	S-08	EPA Region V Guidelines		
					Non-Polluted	Moderately Polluted	Heavily Polluted
trans 1,2-DCE	BDL	16-1100	BDL-83	BDL	NA	NA	NA
TCE	BDL	1100-1700	BDL	BDL	NA	NA	NA
phenol	BDL	BDL-3400	BDL	BDL	NA	NA	NA
Total SVOCs		BDL-380	BDL	BDL-21600	NA	NA	NA
Total Pesticides	BDL	BDL	3.7-167.8	BDL-800	NA	NA	NA
Navy Soil Samples (mg/kg)							
	Range		Mean				
oil & grease	4120-54,100		24,588		<1000	1000-2000	>2000

BDL = Below method detection limit

NA = No applicable standard

Note: See Appendix A for complete analytical data from the interim RI

Table 1-2

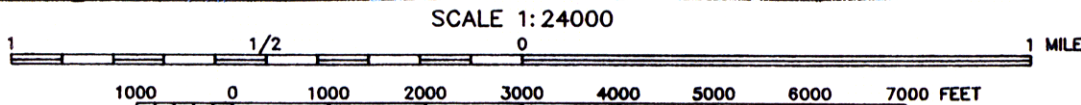
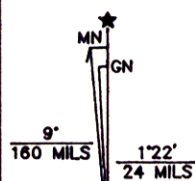
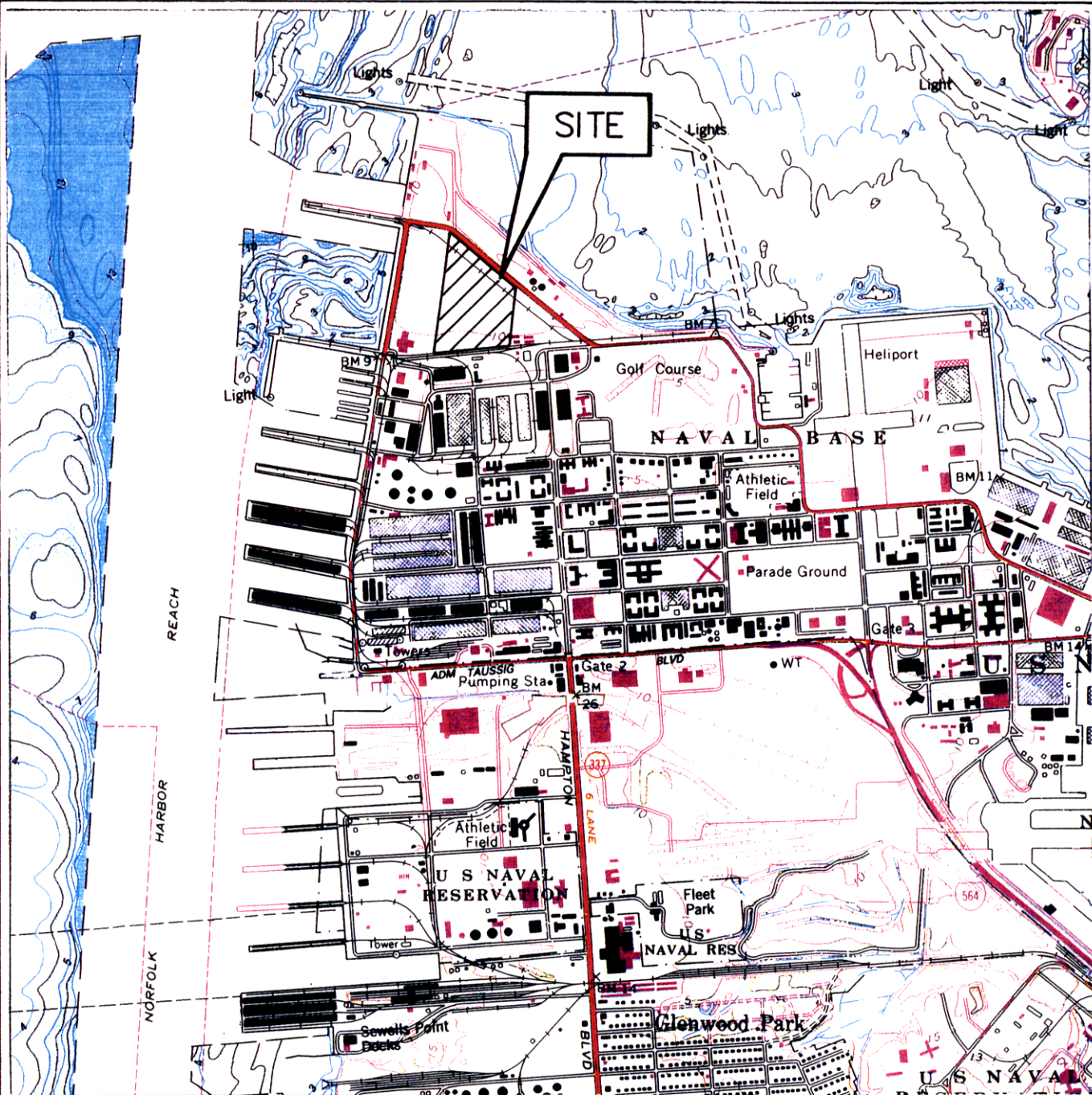
## Summary of Interim RI Groundwater Analytical Results

VOC Results (µg/l)						
	GW-01	GW-02	GW-03	GW-04	EPA Drinking Water Standards	EPA Water Quality Standards
vinyl chloride	BDL-24	BDL	BDL	BDL	2	NA
trans 1,2-DCE	5600-9000	BDL	BDL	BDL	0.33	11600
TCE	1000-6000	BDL	BDL	BDL	27	45000
PCE	BDL-19	BDL	BDL	BDL	0.8	450
IOC Results (mg/l)						
	GW-01	GW-02	GW-03	GW-04	VDEQ Groundwater Standard	
arsenic	BDL-0.20	BDL-0.13	BDL-0.20	BDL-0.50	0.05	
cadmium	0.01-0.02	BDL-0.02	BDL-0.09	BDL	0.0004	
chromium	BDL-0.10	BDL-0.22	BDL-0.45	0.08-140.00	0.05	
lead	BDL-0.30	BDL-0.23	BDL-0.32	BDL	0.05	
mercury	BDL	BDL-0.00007	BDL-0.001	BDL-0.00078	0.00005	
zinc	BDL-0.30	0.04-0.30	BDL-0.40	0.05-0.30	0.05	
Oil and Grease Results (mg/l)						
	GW-01	GW-02	GW-03	GW-04		
oil and grease	BDL-80	BDL-74	BDL-40	7-610		

BDL = Below method detection limit

NA = No applicable standard

Note: See Appendix A for complete analytical data from the interim RI.



CONTOUR INTERVAL 10 FEET  
NATIONAL GEODETIC VERTICAL DATUM OF 1929

SOURCE: USGS NORFOLK NORTH, VA. QUADRANGLE

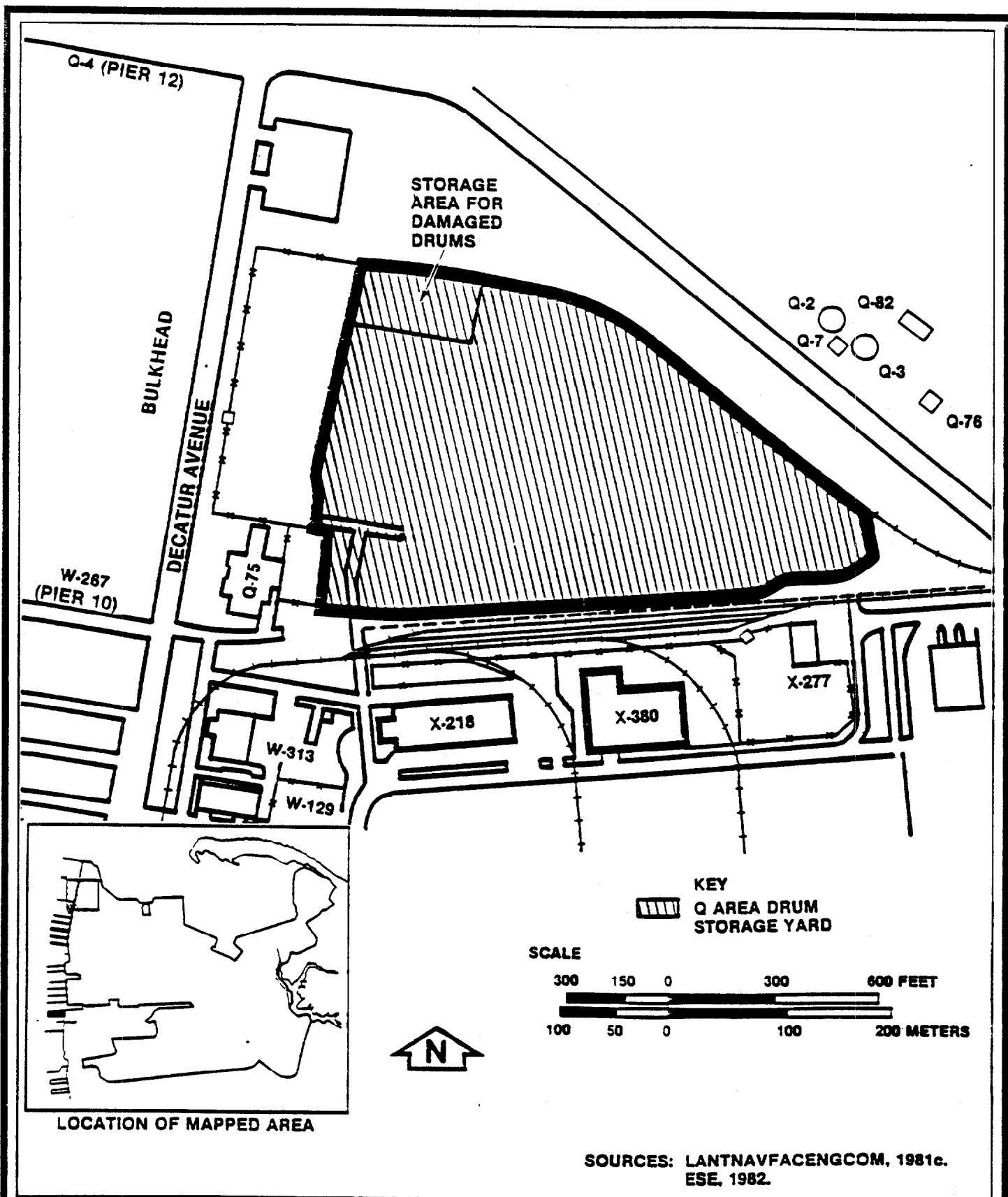
UTM GRID AND 1984  
MAGNETIC NORTH  
DECLINATION AT  
CENTER OF SHEET



Environmental  
Science &  
Engineering

DATE 6-3-91	SCALE SHOWN	TITLE Site Location Map - Q Area Drum Storage Yard - Norfolk Naval Base - Norfolk, Virginia	
DRAWN BY LAF	APPROVED BY		
JOB NO. 4901107	DWG. NO./ REV. NO. 1 -	CLIENT NAVFAC LANTDIV - Q AREA	FIGURE 1-1

01108R02 X



Environmental  
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DATE  
6-3-91

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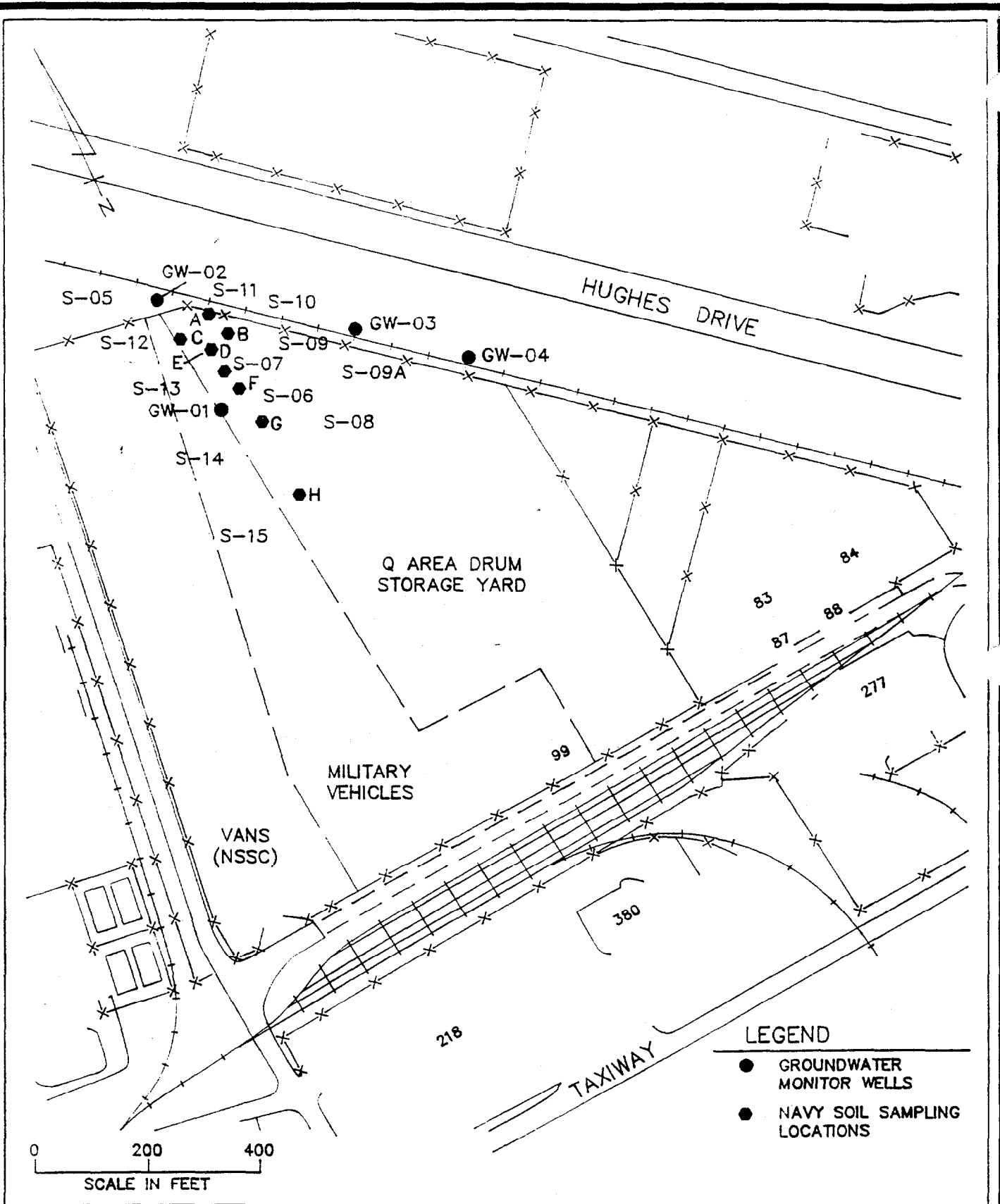
APPROVED BY

DWG. NO. / REV. NO.  
2 -

TITLE  
Area of Investigation for Initial  
Assessment Study, May 1982, Q Area  
Drum Storage Yard, Norfolk Virginia

CLIENT  
LANTNAVFACENGCOM

FIGURE  
1-2



**Environmental  
Science &  
Engineering**

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**LAF**

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**4901107**

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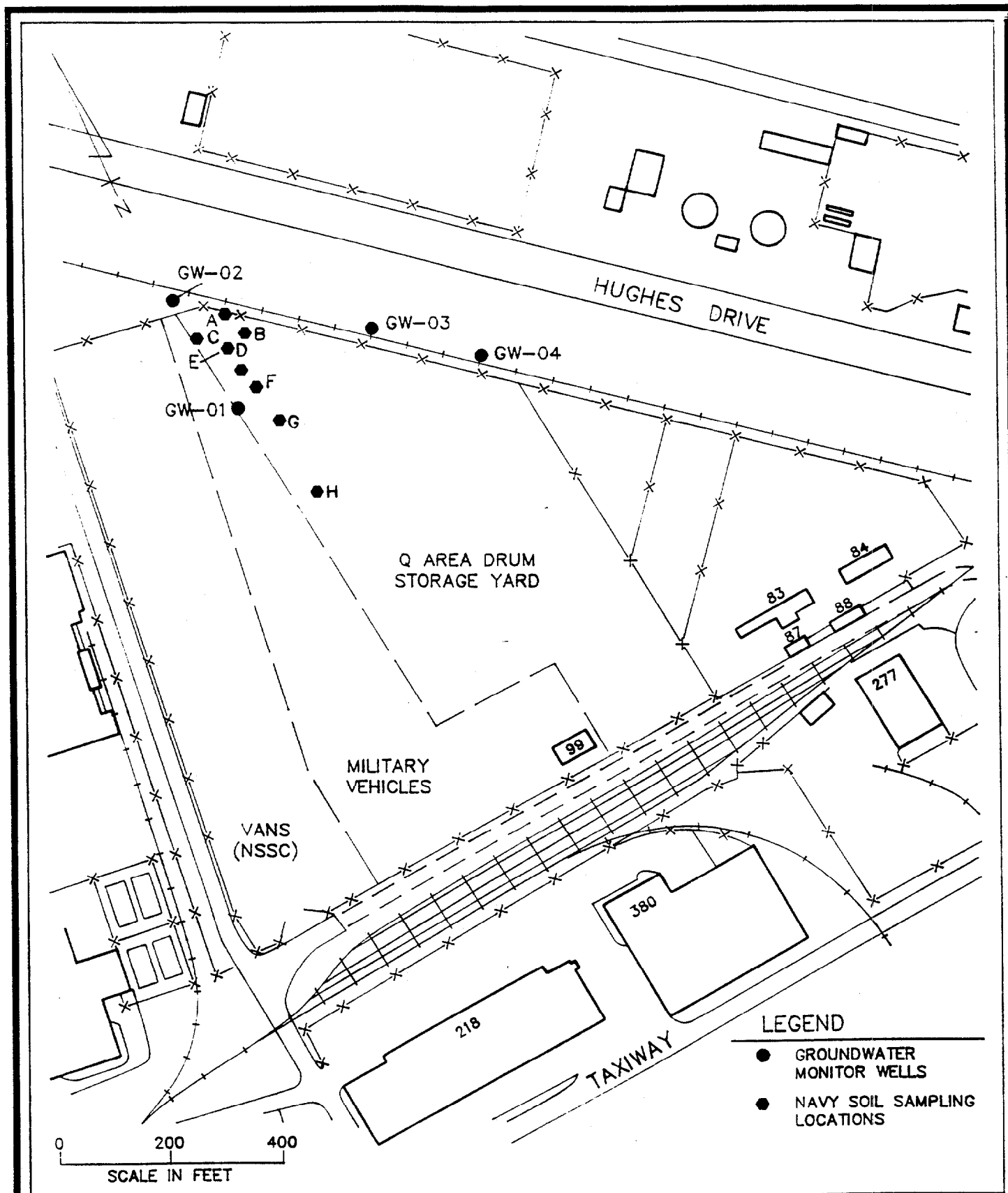
APPROVED BY

DWG. NO. / REV. NO.  
**QBASE3 / -**

TITLE  
**Area of Investigation for the Remedial  
Investigation, November 1983-June 1986  
Q Area Drum Storage Yard, Norfolk, Va**

CLIENT  
**LANTNAVFACENGCOM**

FIGURE  
**1-3**



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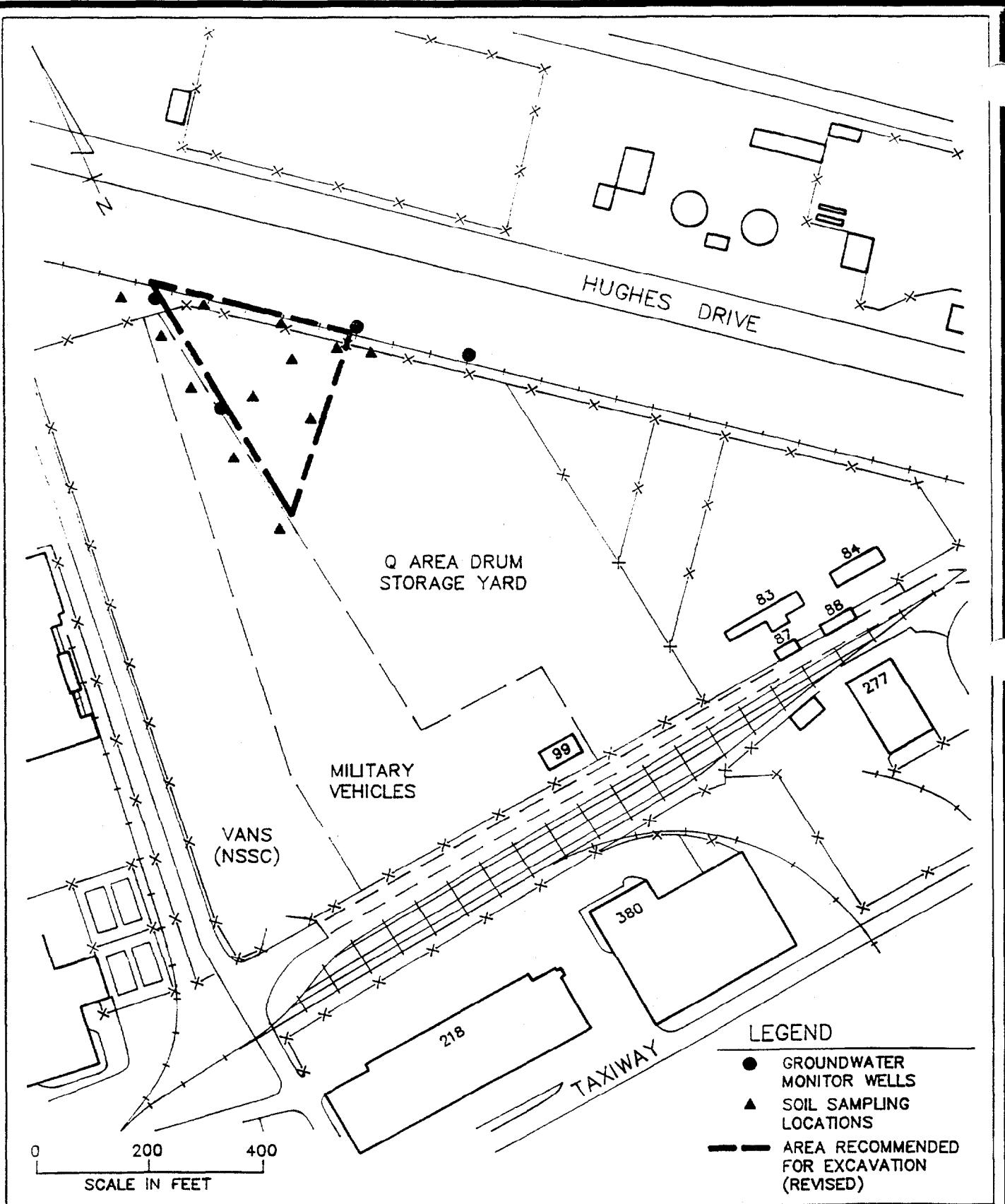
DWG. NO./ REV. NO.  
QBASE1 / -

TITLE  
Navy Sampling Locations,  
April 1986 - Q Area Drum  
Storage Yard - Norfolk, VA

CLIENT  
LANTNAVFACENGCOM

FIGURE  
1-4





**Environmental  
Science &  
Engineering**

DATE  
6-4-91

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JOB NO.  
4901107

SCALE  
SHOWN

APPROVED BY

DWG. NO. / REV. NO.  
QBASE2 / -

TITLE  
Area Recommended for  
Contaminated Soil Removal  
Q Area Drum Storage Yard, Norfolk, Va

CLIENT  
LANTNAVFACENGCOM

FIGURE  
1-5



## 2.0 STUDY AREA INVESTIGATION

### 2.1 Field Investigation Methods

The methods employed during the field investigation for the QADSY RI were selected to meet the data needs established in the IAS and interim RI reports. An overview of the field activities follows, as outlined in the work plan (Environmental Science and Engineering (ESE), September 1990) sampling and analysis plan (ESE, November 1993). These methods were required to determine if the site is releasing hazardous substances, pollutants, or contaminants into the environment that may require a removal action. The work included identifying and quantifying pollutant concentrations and contamination extent.

For the purpose of the field investigation, the QADSY was divided into five areas:

1. Hazardous Materials area (HM)
2. Petroleum Products area (PPA)
3. Transit Area (TA)
4. Truck and Equipment Storage Yard (EY)
5. Fleet Parking (FP) west of the QADSY

The rationale for these categories is explained in detail in Sections 3.1 and 3.2.

#### 2.1.1 Surface Features

Surface features of the QADSY were investigated to determine potential contaminant migration paths. Photographs taken of the site during the field investigation and sampling operations are included as Appendix B. Onsite features such as storm sewers, surface topography, obvious spill locations, stained soils, and other specifics were noted in the field notebook (Appendix C).

#### 2.1.2 Contaminant Source Investigations

A site visit was conducted prior to initiating field activities to determine the nature of potential onsite contaminant sources. An ESE representative met with the Navy Engineer-in-Charge (EIC) at the QADSY on 15 June 1990 for a walk-through and to discuss the history of the site. Drum contents and storage practices were noted, and personnel familiar with the site were interviewed to determine the material storage practices through time.

Soil staining and evidence of spills were noted during the site visit. Sampling locations were chosen to randomly cover several typical scenarios found in the QADSY; i.e., obvious spill

locations, apparently clean locations, areas proximate to the concrete footings where the drums were stored, etc.

### **2.1.3 Geological Investigation**

Site geology is required to fully determine the nature and extent of contamination. Field data are compared with available resources; this information is vital in determining the geologic formations and water-bearing zones underlying the site. The regional geology was determined from available information prior to the field investigation (Section 3.5.1), and the subsurface exploration was subsequently performed.

Subsurface exploration consisted of mobilizing a truck-mounted drill rig in September and October 1990. Ten borings were advanced using continuous-flight, hollow-stem augers: two (DW-1 and DW-2) were advanced to 45 feet, and the remaining eight shallow borings (SW-1 through SW-8) were advanced to 25 feet. Soil samples were taken continuously to the water table, then every 5 feet to the total depth of each boring for ten of the borings.

Additional subsurface exploration consisted of mobilizing a truck-mounted drill rig in January 1993. Eight borings were advanced using continuous-flight, hollow-stem augers: two (SW-9 and SW-10) were advanced to 35 feet, one (DW-8) was advanced to 40 feet, two (DW-5 and DW-6) were advanced to 45 feet, one (DW-7) was advanced to 50 feet, and two (DW-3 and DW-4) were advanced to 65 feet. Soil samples were collected continuously from 45 to 65 feet for two borings (DW-3 and DW-4) located adjacent to the cluster monitor wells. Soil samples were collected continuously for the remaining six borings.

A geologist classified each sample and logged the lithology on boring logs (Appendix D). The boring locations are shown on Figure 2-1.

### **2.1.4 Surface Soil Investigation**

Surface soil properties influence the type and rate of contaminant movement to the subsurface and subsequently to the water table. Contaminants that can move through the surface soil and the vadose zone may move directly to the water table or may be partially or fully retained within the vadose zone to act as continued sources of groundwater contamination. Characterizing surface soils can assist in determining contaminant impacts on the groundwater.

Surface soil samples were collected from 36 locations within and adjacent to the QADSY in September and October 1990. Borings TA-1 through TA-5, HM-3, HM-5, and HM-9 were advanced using the hollow-stem auger method and sampled with split-spoon samplers (ASTM Method D-1586). The remaining samples were collected using a hand auger. A geologist classified the soil type at each location and measured the total organic vapor (TOV) using an organic vapor analyzer (OVA).

Samples were collected from two intervals in 24 of the borings: 0 to 18 inches and 18 to 36 inches. Composite samples were collected from the 12 remaining borings between 0 and 36 inches (one sample per boring). Each sample was composited in a decontaminated stainless steel container, placed in prelabeled sample bottles, and placed on ice (4°C) in coolers for shipment. After soil sampling was completed at each of the 36 locations, the boreholes were backfilled with auger cuttings.

A total of 48 samples from the 24 borings were analyzed for VOCs and TPH, 41 for TCLP metals, 18 for SVOCs and pH, 5 for TOX, and 4 for percent moisture in September and October 1990. The samples collected from the 12 remaining borings were analyzed for full TCLP parameters and were used as a screening tool to determine all potential contaminants found at the site. Background samples were collected from two of the monitor well borings: BGSS-1-1 and BGSS-1-2 were collected from boring SW-8, and BGSS-2 was collected from boring DW-2. Six duplicate soil samples were collected from the following locations: HM-4-1, HM-1, PP-3-1, PP-14-2, EY-5-2, and EY-7-2. All samples were shipped overnight via Federal Express to CEIMIC's laboratory in Narragansett, Rhode Island. The boring locations are shown on Figure 2-2, and Table 2-1 summarizes the sampling analysis for each location.

Baker Environmental, Inc. collected 19 subsurface soil samples in May 1995, 15 of which were analyzed for TPH (SS-1, SS-3 through SS-16). The four remaining samples were analyzed for VOCs, SVOCs, pesticides/PCBs, IOC's, and cyanide. The samples were analyzed by Weston Environmental Matrices, Inc. in University Park, Illinois.

### **2.1.5 Subsurface Soil Investigation**

Subsurface soil samples were collected to determine the vertical and lateral extent of TPH contamination in the onsite soils. Sixteen soil samples were collected for analytical purposes from eight power-drilled auger borings in December 1992. The borings were advanced using a 1.5-inch solid-stem auger method and sampled ahead of the augers using a stainless-steel thin-walled collection tube and slide hammer attachment. Samples were collected from two intervals in the eight borings: 3 to 5 feet and 5 to 7 feet. Each sample was composited in a decontaminated stainless steel container, placed in prelabeled sample bottles, and placed on ice (4°C) in coolers for shipment. Field duplicates were not collected for the subsurface investigation. After soil sampling was completed at each of the eight locations, the boreholes were backfilled with auger cuttings.

The sixteen samples were analyzed for TPH (Table 2-1). All samples were shipped overnight via Federal Express to ESE's laboratory in Gainesville, Florida. The boring locations are shown on Figure 2-2.

### **2.1.6 Sediment Investigation**

Sediment samples were collected to determine if surface contamination is traveling directly into the storm drain that flows into the Elizabeth River. Two sediment samples were collected in the storm drain south of monitor well SW-4 (SD-1) and north of the onsite trailer (SD-2). The samples collected from the storm drains were analyzed for full TCLP parameters (Figure 2-2).

### 2.1.7 Groundwater Investigation

Groundwater quality, site hydrogeology, and hydraulic properties of the aquifer (e.g., yield, transmissivity, storativity) were determined to assist in evaluating the extent and degree of contamination. Groundwater monitor wells were installed in the 18 borings described in Section 2.1.3; well locations were chosen to detect onsite contamination and offsite contaminant migration. The wells were placed in successively downgradient positions to monitor the potential migration of contaminants from the HM, PPA, and TA areas (Figure 2-1). The monitor wells were located by a licensed surveyor (CEGG Partnership) to state planar coordinates and top of casing and ground elevations to mean sea level (msl). Hydraulic gradient maps were developed by measuring static water levels at each well and calculating their elevation relative to msl. Monitor well survey and groundwater levels are included in Appendix E.

Eight deep wells were installed to test the deeper aquifer zone. No confining layer was encountered between the shallow wells and the base of the deep wells, indicating that the shallow and deep wells are hydraulically connected.

Sixteen monitor wells were constructed of 2-inch ID, flush joint, threaded PVC well screen, riser, and casing. The other two wells (SW-3 and DW-1) were constructed of 6-inch ID, flush joint, threaded PVC well screen, riser, and casing. Table 2-2 summarizes the well construction for all monitor wells; Figure 2-3 illustrates a typical monitor well construction diagram. A sand pack (#2 Morie sand or equivalent) was placed around the slotted well screen and extended to approximately 2 feet above the top of the screen. A 0.01-inch slotted PVC well screen was used in each well, and a bentonite seal (thickness ranged from 1.6 foot to 5 feet) was placed on top of the sand pack. Finally, a grout mixture of two parts sand and one part cement, thoroughly mixed with the specified amount of potable water, was placed in the borehole to ensure a proper seal. Well construction diagrams are included in Appendix F.

Water and drilling mud were required to install monitor wells DW-1 and DW-2, as a result of "running" sands. Water for well installation was obtained from a potable water source (a local fire hydrant) selected by the Navy. Because the drilling mud quality was not predetermined, a mud sample was analyzed to ensure freedom from contaminants of interest. Analyses for the drilling mud are included in Appendix G.

All wells were developed following installation to remove fine-grained materials that may have entered during construction by removing the well volume three to five times by continuous low-yield pumping. All fluids generated from well development were contained in Department of Transportation (DOT)-approved 55-gallon drums. Contaminated fluid disposal was not within the scope of this project and was the responsibility of the Navy.

Groundwater samples were collected from each of the 18 new wells and three existing shallow wells. To evaluate groundwater quality, the following procedures were used to collect the samples:

1. Samples were collected a minimum of seven days after development to allow the wells to reach equilibrium.
2. Immediately prior to collecting a sample, the static water level was measured below the top of the well PVC casing and recorded in the field notebook.
3. Wells were sampled according to degree of contamination: wells expected to be uncontaminated were sampled first, followed by those with potentially increasing levels of contamination.
4. Prior to collecting a sample, the volume of water in the well casing and annulus was purged three to five times until water temperature, specific conductivity, and pH had stabilized. The total amount of fluid purged was measured and recorded.
5. Well sampling was performed with a precleaned stainless steel bailer. All sampling equipment was decontaminated between sampling events according to procedures outlined in the sampling and analysis plan. The bailer was rinsed once with well water prior to collecting a sample (the first bail was discarded). Each shallow well was sampled at the top of the screen (10 to 15 feet from topographic surface) and near the base of the well screen (25 feet) for VOCs, TPH, and pH. Samples for PP metals were also taken from the 25-foot interval in wells SW-1 through SW-5 and SW-8 in October 1990 and the three existing wells GW-1, GW-3, and GW-4 in January 1991. Wells DW-1 and DW-2 were sampled from the 35- to 40-foot interval for VOCs and pH in October 1990. Table 2-3 summarizes the sampling analysis from each well.
6. Additional well sampling was performed with the same procedures as above. Filtered and non-filtered samples for PP metals were collected on October 1992 from the top of the well screen and well bottom in wells SW-2, SW-5, SW-8, DW-1, and DW-2. Groundwater was filtered in the field using a 0.45-micron disposable filter for PP metals. Samples for TCE, PCE, and DCA were collected in January 1993 from top of the well screen and well bottom intervals

at SW-9, SW-10, and DW-8 and the well bottom at DW-3 through DW-7. Table 2-3 summarizes the sampling analysis from each well.

A total of 66 groundwater samples were collected from 18 locations using the hydropunch sampling technique in December 1992 (Figure 2-1). A 2-inch stainless steel outer casing with a drive shoe containing a 1.5-inch diameter sampling tube was placed inside the hollow-stem augers. The sampling tube was hydraulically driven 5 feet below the augers into the undisturbed material to the required depth. The sampling port was revealed for approximately 15 minutes and then withdrawn from the borings. The groundwater samples were placed into two clean, prelabeled 40-milliliter (ml) volatile organic containers.

The samples were analyzed for TCE, PCE, and DCA using a Photovac field gas chromatograph. At least two hydropunch samples were collected at each location. Groundwater samples were collected at 10-foot intervals beginning at 15 feet below surface. Hydropunch samples were collected until the contaminants were found below detection limits or two consecutive samples were detected at or below 5 micrograms per liter ( $\mu\text{g/l}$ ). After the hydropunch sample was completed, soil cuttings were replaced into the borehole to 1 foot below surface and then filled with cement to the surface.

Baker Environmental collected groundwater samples from DW-3 through DW-8, SW-9, and SW-10 in May 1995 for VOCs, SVOCs, pesticides/PCBs, IOC, and cyanide analysis. Prior to collecting each sample, the volume of water in the well casing and annulus was purged three to five times until temperature, turbidity, and pH had stabilized. The total amount of fluid purged was measured and recorded.

Continuous water level monitoring was conducted at SW-1 and DW-1 to define the tidal and recharge influences on the rate and direction of groundwater flow. A pressure transducer was installed in two wells (SW-1 and DW-1) and connected to a Hermit datalogger to measure the potentiometric head. Water level measurements were collected every hour for 34 days.

Vertical flow regime between the site aquifer and the Elizabeth River was determined by temporarily installing a 2-inch PVC piezometer at the end of Pier 11. The piezometer (1-foot screen) was driven approximately 2.5 feet below the stream bottom surface. The volume of water in the well casing was purged five times. The development water was discharged directly into the Elizabeth River. After the water quality parameters stabilized from development, one pressure transducer was installed in the piezometer and connected to a Hermit datalogger to measure the potentiometric head. Another pressure transducer was placed inside a plastic bucket (with holes) in the river adjacent to the piezometer. The purpose of the plastic bucket was to eliminate splashing or moving the pressure transducer, resulting in unacceptable data. Readings from the piezometer and river were recorded every hour for approximately eight days. The head difference between the piezometer and the river was used to determine vertical flow between the underlying aquifer and the river.

A constant rate test is the most valuable tool to determine an aquifer's hydraulic characteristics. To determine the performance characteristics and hydraulic parameters of the unconfined aquifer, a 72-hour constant rate drawdown test was performed using monitor well SW-3. The specific capacity, transmissivity, storage coefficient, and the area of influence were determined and are described in Section 4.0.

A submersible pump was used to withdraw groundwater at a constant rate of 5.2 gpm for 72 hours, creating a cone of depression within the QADSY. A discharge line connected to the pump withdrew the effluent during the testing period. The discharge line was equipped with a valve gate and an accumulator meter to determine the flow rate and the total effluent discharged. The water was contained onsite and treated at the Navy water treatment plant to prevent potential groundwater contamination and to eliminate artificial recharge.

The drawdown and recovery of the pumping well and six shallow observation wells were monitored with pressure transducers (5 psi) and recorded at specific time intervals on a datalogger. Tidal influences were considered in the hydraulic calculations due to the proximity of the site to Willoughby Bay. Two wells (SW-6 and SW-8) were monitored to calculate tidal influence on water table fluctuation. "True" drawdown in the observation wells was calculated by compensating for tidal fluctuation.

Slug tests were also performed on all shallow wells except SW-3. A slug, constructed from a 10-foot length of 1-3/8-inch OD, Schedule 40 PVC pipe filled with washed silica sand and sealed at each end, was lowered into each well to produce an instantaneous rise in the water level. Water level recovery over time was monitored using a water level/interface probe. Once the water level reached equilibrium, the slug was removed rapidly from the well and the recharge was monitored over time using the water level/interface probe. The slug, probes, and rope were decontaminated between locations according to the procedures set forth in the sampling plan.

Data files were created from pumping test and slug test data for use with AQTESOLV®, a personal computer program to analyze aquifer test data. Aquifer characteristics (transmissivity, specific yield, and hydraulic conductivity) were then calculated for the unconfined aquifer conditions of the QADSY.

MODFLOW, a three-dimensional groundwater flow model was used to determine groundwater flow lines at the QADSY. The flow lines can be used to interpret pathlines and capture zones for predicting the behavior of contaminant plumes under various pumping scenarios in the horizontal as well as vertical migration pathways. The model will present the interconnection between surface water and groundwater. INTERTRANS, a three dimensional particle tracking solute transport model developed by ESE, was used to determine if the contaminants migrating from the QADSY will discharge into the Elizabeth River.

### 2.1.8 Surface Water Investigation

One background surface water sample was collected from the Elizabeth River between Piers 10 and 11 in October 1992 and analyzed for PP metals (Figure 2-1). Both a filtered and an unfiltered sample were shipped overnight to ESE's Gainesville, Florida laboratory.

**Table 2-1**  
**Summary of Monitor Well Installation**

<b>Monitor Well</b>	<b>Total Depth (feet)</b>	<b>Screen Interval (feet)</b>	<b>Casing Type &amp; Size</b>	<b>Bentonite Seal Thickness (feet)</b>	<b>Grout Thickness (feet)</b>
DW-1	45	35-45	6-inch PVC	2.5	30
DW-2	45	35-45	2-inch PVC	4	27.5
DW-3	65	55-65	2-inch PVC	5	45
DW-4	65	55-65	2-inch PVC	5	45
DW-5	45	35-45	2-inch PVC	5	25
DW-6	45	35-45	2-inch PVC	5	25
DW-7	50	40-50	2-inch PVC	5	30
DW-8	40	15-40	2-inch PVC	5	5
SW-1	25	10-25	2-inch PVC	2	6
SW-2	25	10-25	2-inch PVC	2.5	5
SW-3	25	5-25	6-inch PVC	3.5	1.5
SW-4	25	10-25	2-inch PVC	1.6	5.9
SW-5	25	10-25	2-inch PVC	2.5	4.5
SW-6	25	10-25	2-inch PVC	2.5	5
SW-7	25	10-25	2-inch PVC	2	6
SW-8	25	10-25	2-inch PVC	2	6
SW-9	35	15-35	2-inch PVC	5	5
SW-10	35	15-35	2-inch PVC	5	5



**Table 2-2. Soil Analysis Summary**

<b>HAZARDOUS MATERIALS AREA</b>		
<b>Soil Boring Samples</b>		
HM-1	0 to 36"	TCLP
HM-2 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
HM-2 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
HM-3 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
HM-3 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
HM-4 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
HM-4 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
HM-5 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
HM-5 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
HM-6	0 to 36"	TCLP, TOX
HM-7 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
HM-7 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
HM-8	0 to 36"	TCLP
HM-9 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
HM-9 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
HM-10 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
HM-10 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
SB-6 #4	3 to 5'	TPH
SB-6 #6	5 to 7'	TPH
SB-7 #4	3 to 5'	TPH
SB-7 #6	5 to 7'	TPH
SB-8 #4	3 to 5'	TPH
SB-8 #6	5 to 7'	TPH
SS-1	0 to 18"	TPH
SS-3	0 to 18"	TPH

**Table 2-2. Soil Analysis Summary (Continued)**

SS-4	0 to 18"	TPH
SS-5	0 to 18"	TPH
SS-6	0 to 18"	TPH
SS-7	0 to 18"	TPH
SS-8	0 to 18"	TPH
SS-17	0 to 18"	VOCs, SVOCs, Pesticides/PCBs, IOCs, Cyanide
<b>Monitor Well Samples</b>		
SW-1 Soil	0 to -10	TCLP
SW-2 Soil	0 to -10	VOCs, TPH, pH
<b>PETROLEUM PRODUCTS AREA</b>		
<b>Soil Boring Samples</b>		
PP-1	0 to 36"	TCLP
PP-2 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
PP-2 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
PP-3 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-3 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-4	0 to 36"	TCLP, TOX
PP-5 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
PP-5 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
PP-6 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-6 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-7	0 to 36"	TCLP
PP-8 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
PP-8 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
PP-9 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-9 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-10	0 to 36"	TCLP, TOX

**Table 2-2. Soil Analysis Summary (Continued)**

PP-11 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
PP-11 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
PP-12 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-12 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
PP-13	0 to 36"	TCLP
PP-14 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
PP-14 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
SB-2 #4	3 to 5'	TPH
SB-2 #6	5 to 7'	TPH
SB-3 #4	3 to 5'	TPH
SB-3 #6	5 to 7'	TPH
SB-4 #4	3 to 5'	TPH
SB-4 #6	5 to 7'	TPH
SB-5 #4	3 to 5'	TPH
SB-5 #6	5 to 7'	TPH
SS-13	0 to 18"	TPH
SS-14	0 to 18"	TPH
SS-15	0 to 18"	TPH
SS-16	0 to 18"	TPH
SS-18	0 to 18"	VOCs, SVOCs, Pesticides/PCBs, IOCs, Cyanide
<b>Monitor Well Samples</b>		
SW-3 (6") Soil	0 to -10'	VOCs, TPH, TCLP (metals), % moisture
SW-4 Soil	0 to -10'	TCLP
SW-4 #1 Water	-15'	VOCs, TPH, pH
SW-4 #2 Water	-25'	VOCs, TPH, pH, IOCs

**Table 2-2. Soil Analysis Summary (Continued)**

<b>TRANSIT AREA</b>		
<b>Soil Boring Samples</b>		
TA-1 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
TA-1 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
TA-2	0 to 36"	TCLP
TA-3 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
TA-3 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
TA-4	0 to 36"	TCLP, TOX
TA-5 #1	0 to 18"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
TA-5 #2	18 to 36"	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH
SB-1 #4	3 to 5'	TPH
SB-1 #6	5 to 7'	TPH
SS-9	0 to 18"	TPH
SS-10	0 to 18"	TPH
SS-11	0 to 18"	TPH
SS-12	0 to 18"	TPH
SS-19	0 to 18"	TPH
SS-20	0 to 18"	VOCs, SVOCs, Pesticides/PCBs, IOCs, Cyanide
<b>Monitor Well Samples</b>		
SW-5 Soil	0 to -10'	TCLP
<b>TRUCK/EQUIPMENT YARD</b>		
<b>Soil Boring Samples</b>		
EY-1	0 to 36"	TCLP, TOX
EY-2 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
EY-2 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
EY-3 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
EY-3 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture

**Table 2-2. Soil Analysis Summary (Continued)**

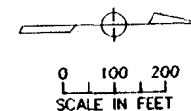
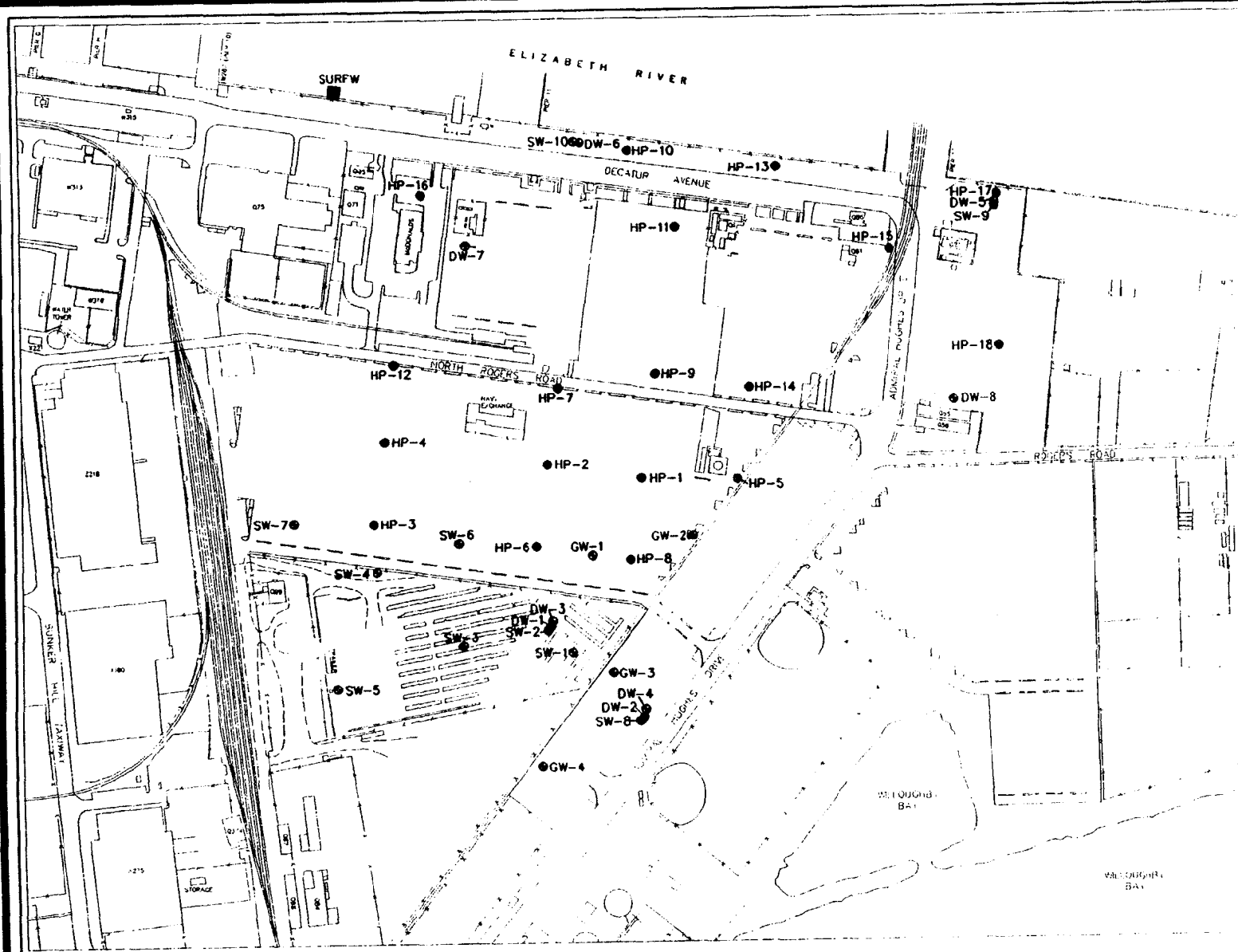
EY-4 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
EY-4 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
EY-5 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
EY-5 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
EY-6	0 to 36"	TCLP
EY-7 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
EY-2 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
<b>BACKGROUND</b>		
<b>Soil Samples</b>		
BGSS-1 #1	0 to 18"	VOCs, TPH, TCLP (metals), % moisture
BGSS-1 #2	18 to 36"	VOCs, TPH, TCLP (metals), % moisture
BGSS-2 #2	0 to 36"	SVOCs, pH, TOX
<b>DRILLING MUD</b>		
Mud Sample	N/A	VOCs, SVOCs, TPH, TCLP (metals), % moisture, pH, TOX

Table 2-3. Groundwater Analysis Summary

Well	October 1990	January 1991	October 1992	January 1993	May 1995
DW-1	VOCs, pH		IOCs		
DW-2	VOCs, pH		IOCs		
DW-3				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs
DW-4				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs
DW-5				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs
DW-6				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs
DW-7				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs
DW-8				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs
GW-1	VOCs, TPH, pH	IOCs			
GW-3	VOCs, TPH, pH	IOCs			
GW-4	VOCs, TPH, pH	IOCs			
SW-1	VOCs, TPH, pH, IOCs	IOCs			
SW-2	VOCs, TPH, pH, IOCs	IOCs	IOCs		
SW-3	VOCs, TPH, pH, IOCs	IOCs			

**Table 2-3. Groundwater Analysis Summary (continued)**

Well	October 1990	January 1991	October 1992	January 1993	May 1995
SW-4	VOCs, TPH, pH, IOCs	IOCs			
SW-5	VOCs, TPH, pH, IOCs	IOCs	IOCs		
SW-6	VOCs, TPH, pH, IOCs				
SW-7	VOCs, TPH, pH, IOCs				
SW-8	VOCs, TPH, pH, IOCs	IOCs	IOCs		
SW-9				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs
SW-10				TCE, PCE, DCA	VOCs, SVOCs, Pesticides/ PCBs, cyanide, and IOCs



# LEGEND

- HYDROPUNCH LOCATION
- MONITOR WELL LOCATION
- SURFACE WATER LOCATION



Environmental  
Science &  
Engineering

A CECO Corporation

DATE  
9-20-95

DRAWN BY  
JTG

JOB NO.  
4921150

SCALE  
SHOWN

APPROVED BY

DWG. NO. / REV. NO.  
SURF150

TITLE

MONITOR WELL, HYDROPUNCH, AND  
SURFACE WATER LOCATIONS  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

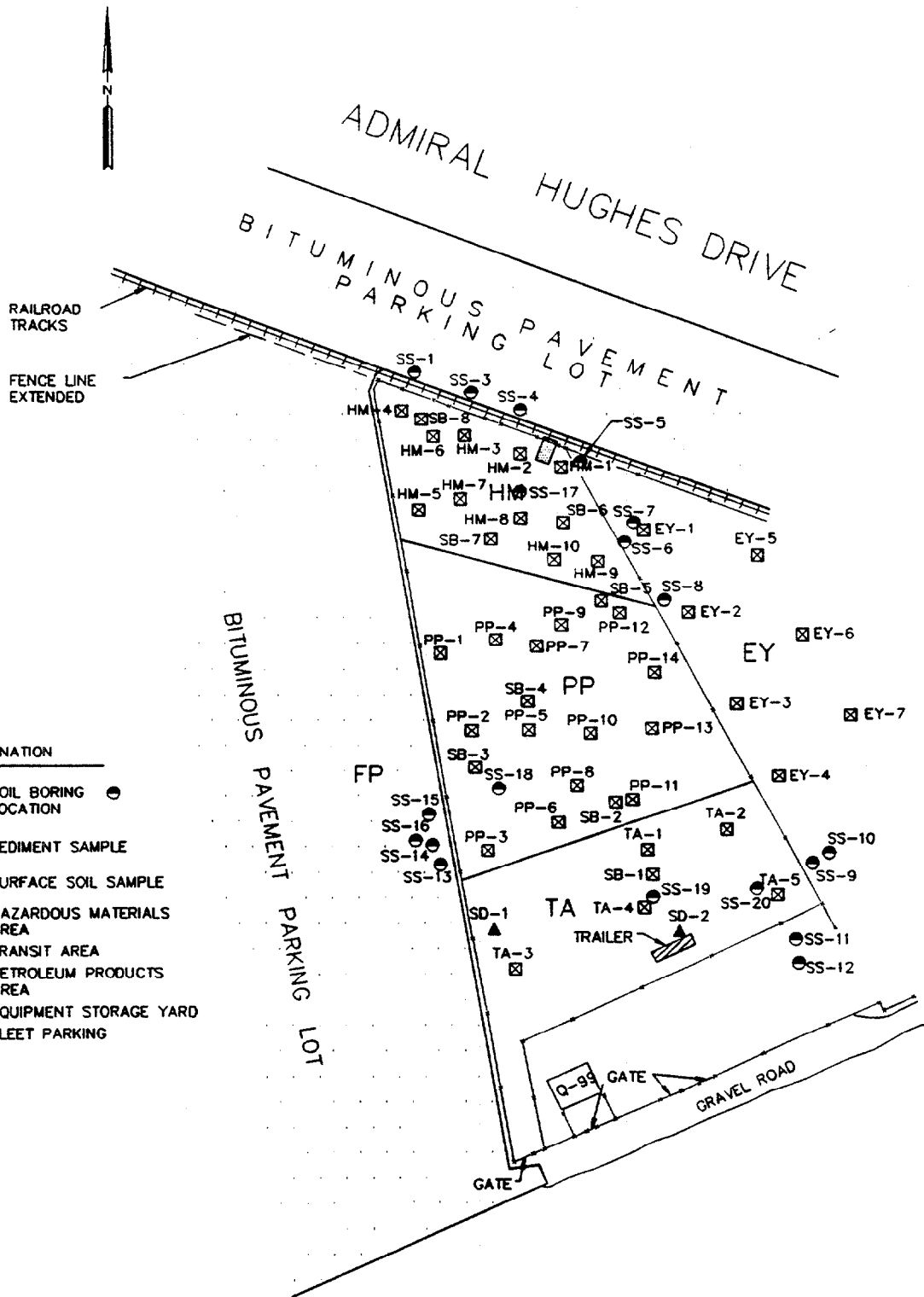
CLIENT

NAVFAC - Q AREA

FIGURE

2-1





#### EXPLANATION

- PP-3 SOIL BORING LOCATION  
 SS-1 SEDIMENT SAMPLE  
 SD-1 SURFACE SOIL SAMPLE  
 HM-HAZARDOUS MATERIALS AREA  
 TA-TRANSIT AREA  
 PP-PETROLEUM PRODUCTS AREA  
 EY-EQUIPMENT STORAGE YARD  
 FP-FLEET PARKING

MAP SOURCE:  
 PLAT MAP DRAWN BY  
 THE CEGG PARTNERSHIP  
 DATED FEBRUARY 22, 1991.

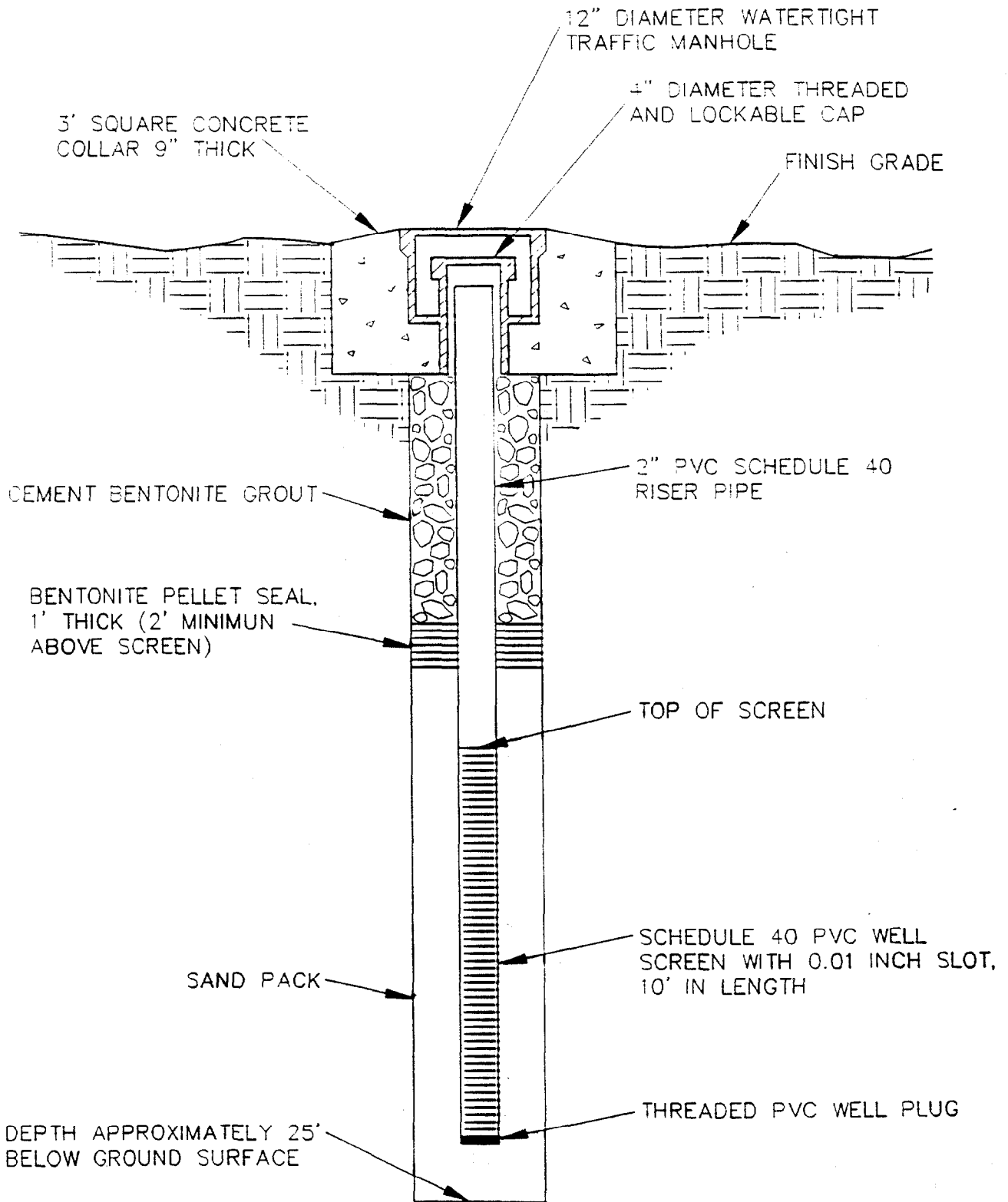
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Environmental  
 Science &  
 Engineering

DATE 10-11-95	SCALE SHOWN	TITLE SOIL AND SEDIMENT SAMPLE LOCATIONS Q AREA DRUM STORAGE YARD NORFOLK, VIRGINIA	
DRAWN BY TJF	APPROVED BY		
JOB NO. 4921150	DWG. NO./ REV. NO. SOILB2 /	CLIENT NAVFAC - Q AREA	FIGURE 2-2



Environmental  
Science &  
Engineering

DATE  
4-6-93

DRAWN BY  
DN/LAF

JOB NO.  
4921150

SCALE  
N.T.S.

APPROVED BY

DWG. NO. / REV. NO.  
MWCD / -

TITLE  
MONITOR WELL CONSTRUCTION DETAIL  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
NAVFAC - Q AREA

FIGURE  
2-3

### 3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

The physical characteristics of the study area were evaluated using a variety of office and field methods. Topographic and other maps were readily available, as were records concerning the local climate, demographics, etc. Field methods were required to investigate the geology and hydrogeology of the study area. The methods employed in obtaining the data are discussed in Section 2.0.

#### 3.1 Surface Features

The QADSY is located in the northernmost portion of the Norfolk Naval Base (Figure 1-1). The surrounding terrain is flat and even, characteristic of the whole region. The southern portion of the site (south of well SW-3) slopes gently from north to south. The average elevation of the site is about 10 feet above msl.

The site area is fenced off from the surrounding parcels of land, with parking lots (asphalt-paved) situated to the west and the north. A large aboveground storage tank (AST) farm is located 600 feet to the northeast, across Admiral Hughes Drive toward Willoughby Bay. Large equipment storage areas are located to the east of the main fenced area, including the EY area that houses cranes, trucks, backhoes, and other heavy equipment, as well as trailers and containers. A Naval Supply Center (NSC) warehouse is situated to the south; paint and other supplies are stored there.

The fenced portions of the site (HM, PPA, and TA) comprise a gravel/roadbase-paved area, approximately 5 acres in size. Raised concrete slabs protected by wooden frames onto which drums were loaded and stored are arranged in parallel rows in the PPA and HM areas. The slabs are approximately 18 inches above ground level. Much of the framing wood is in poor condition; the wood, concrete, and ground surface of the site were commonly stained to varying degrees with a black, presumably petroleum-based, product(s). Certain portions of the TA are also heavily stained with oil/grease-type compounds.

The spills in the PPA and HM areas appear to have resulted from slow leaks, presumably from ruptured containers stored on the concrete slabs. The spills in the TA appear to be the result of one-time spill incidents; one area, to the west of the trailer area, seems particularly affected.

West of the fenced area, the FP consists of an approximately 29-acre asphalt-paved area used for fleet parking. Drums were suspected to be stored there, but no visible stains were evident.

### 3.2 Contaminant Sources

At the time of the initial QADSY site visit, a large number of 55-gallon drums were stored horizontally, above ground, on concrete footings. A number of damaged drums were stored in the northeastern corner of the site and appear to have leaked at various times. According to onsite personnel, hazardous materials were historically stored in the northern portion of the site.

Soil staining and spills are evident throughout the site and appear to be a source of contamination; spillage appears accidental. The drum contents include petroleum products (hydraulic fluid, engine oil lubricant), solvents (toluene, 1,1,1-trichloroethane (TCA), petroleum naphtha), and other materials (methyl isobutylketone (MIBK), cellulose nitrate).

For the purpose of the RI/FS, the QADSY was divided into five areas:

1. HM: contained hazardous materials such as toluene, MIBK, 1,1,1-TCA, and various solvents.
2. PPA: contained hydraulic fluid, engine oil lubricant, and other petroleum products.
3. TA: contained various products at different times; used as a staging area for drums to be loaded on and unloaded from ships.
4. EY: contains trucks and heavy motorized equipment. Located east of the QADSY fence; however, the footprint of the potential construction extends into the area.
5. FP: suspected historic drum storage west of the QADSY fence.

Sampling locations were chosen to randomly cover several typical scenarios found in the QADSY: obvious spill locations, apparently clean locations, areas proximate to the concrete footings on which the drums are stored, locations in the middle of the rows of drums, and areas with little to no evidence of traffic. Several sampling locations were selected in the TA in a topographically low position so that any runoff percolating into and through the soil might be detected.

### 3.3 Meteorology

The climate of the Norfolk area is classified as oceanic (Siudyla, et al., 1981). Temperature extremes have ranged between 2°F and 105°F, although the average annual temperature is about 60°F. The average annual rainfall is 47 inches and is well distributed throughout the year. Annual rainfall has been reported as low as 23.22 inches and as high as 70.72 inches. No site-specific meteorologic data were collected during the RI/FS field investigation.

### 3.4 Surface Water Hydrology

Drainage of the site and surrounding area is controlled by man-made structures and features. Much of the area is paved, and surface runoff is directed into numerous open storm drains that presumably lead directly to the open waters of the Elizabeth River to the west or to Willoughby Bay to the north. No natural drainage features (creeks, marshes, etc.) were found on or near the site.

Precipitation results in significant infiltration in those areas where pavement is absent, i.e., the main portion of the QADSY. However, excess runoff from the site during sudden events is also collected by open storm drains; at least two such drains were located in the TA, the lowest part of the site.

### 3.5 Geology

#### 3.5.1 Regional Geology

The QADSY is located in the outer Coastal Plain Physiographic Province, characterized by low elevations and relief, sloping gently eastward. The Coastal Plain is defined to the east by the Atlantic Ocean and to the west by the Fall Line near Emporia, Virginia (Frye, 1986). The Coastal Plain is characterized by unconsolidated sediments of Cretaceous, Tertiary, and Quaternary ages that dip gently eastward and rest on pre-Cretaceous aged bedrock at a depth of approximately 2200 feet. The Coastal Plain of Virginia consists of an eastward thickening sedimentary wedge composed principally of unconsolidated gravels, sands, silts, and clays with variable amounts of shells. Coastal Plain deposits cover the length of the Virginia coastline, extending westward to the "fall line," where the pre-Cretaceous basement complex reaches the surface approximately 80 miles westward (Meng and Harsh, 1988).

QADSY is underlain by approximately 15 feet of fill, as described in Section 1.2.1. The edge of the fill is located approximately 2500 feet south of the site (Barker and Bjorken, 1978). Below the fill, the QADSY is underlain by the Upper Pleistocene Lynnhaven Member within the Tabb Formation (Figure 3-1). The strata consist of fine to coarse sand grading upward to sandy and clayey silt. Locally, the base of the unit includes cross-bedded sand and clayey silt containing plant material. The member constitutes surficial deposits of broad swales and extensive lowlands. The average thickness of the Lynnhaven Member is 20 feet (Mixon, et al., 1989).

Throughout the Coastal Plain, groundwater occurs in the unconsolidated, layered sediments. The depositional strata encountered at the site are part of the undifferentiated quaternary sediments of the Columbia aquifer. These sediments are primarily Pleistocene and Holocene in age, but also include sandy Pliocene sediments along the contact with the underlying Yorktown confining unit. The Columbia aquifer is generally unconfined; however, clayey sediments within the aquifer may produce local confined or semi-confined conditions. The

sediments composing the Columbia aquifer consist mostly of a series of formations resulting from Pleistocene marine transgressions (Meng and Harsh, 1988).

According to Siudyla, et al. (1981), the aquifer can be used only for lawn watering and other similar uses due to water quality limitations. The groundwater commonly has a low pH and a high iron content. Regionally, the aquifer has typically been contaminated by:

- Waste lagoons
- Landfills
- Septic tanks below the water table
- Municipal sludge application sites

The City of Norfolk Health Department prohibits the use of the water table aquifer for public or private potable water supplies under law ordinance Chapter 46.1, Reference 46.1-5. All potable water in the City of Norfolk is supplied by the City of Norfolk.

The Yorktown Formation underlies the Tabb Formation and is Miocene in age. The unit is characterized by coarse sand and gravel beds, and abundant, thick shell beds; the formation thickness ranges from 300 to 400 feet.

The Yorktown aquifer is generally encountered under confined (artesian) conditions; the major water-bearing zones are found at depths from 50 to 150 feet (Siudyla, et al., 1981). The aquifer is generally separated from the overlying water table aquifer by 20- to 40-foot thick confining beds of silt, clay, and sandy clay. Leaky confined conditions are encountered in places, and Yorktown recharge commonly occurs through downward leakage from the water table aquifer.

Domestic, public, commercial, and industrial supply wells tap the Yorktown aquifer throughout the region; the water quality is generally suitable for potable and most other uses. However, high iron concentrations are occasionally noted, and brackish water problems (i.e., high chloride content) have also occurred locally. No drinking water wells are used in the vicinity of the site. The Yorktown aquifer at the site adjacent to the Elizabeth River and/or Willoughby Bay is brackish and not used for potable water (Siudyla, et. al., 1981). The Yorktown aquifer discharges into the Elizabeth River and Willoughby Bay. The Elizabeth River and Willoughby Bay water is not used for domestic, public, commercial, or industrial because the surface water is brackish.

### 3.5.2 Site-Specific Geology

The QADSY is underlain by yellow-brown, gray, and black silty sand with shell fragments indicative of the fill material that created the site; brown to black clay lenses are rare from 20 to 30 feet below the ground surface. The water table is approximately 8 feet below the surface, and water table elevations range from 2 to 5 feet above msl. Figure 3-2 indicates the location of the geologic cross-sections (Figure 3-3), which illustrate the subsurface geology at the site as determined from boring logs generated during the RI field effort (Appendix D).

To confirm the field classifications of the subsoils, four representative soil samples of various textures were collected for particle size analysis; the results are presented in Appendix H. The subsoil that underlies the QADSY was determined to be sand with minimal amounts of silt and clay. The Unified Soil Classification System (USCS) symbol for the amount of particles passing through the No. 4 and No. 200 sieves at QADSY is SM.

Porosity ( $n$ ) is an additional aquifer characteristic that can be determined from the particle size analysis. This is calculated by dividing the total unit volume ( $V_t$ ) of soil into its solid portion ( $V_s$ ) and the volume of its voids ( $V_v$ ) where  $n = V_v/V_t$ . The average porosity was calculated in the laboratory to be approximately 25 percent. According to Freeze and Cherry (1979), the range of unconsolidated sands is between 25 and 50 percent. Therefore, the 25 percent value will be used for all groundwater modeling at this site.

## 3.6 Hydrogeology

### 3.6.1 Groundwater Occurrence

Available water supplies at the QADSY site and surrounding area consist of that stored in the pore space of the underlying sediments. As mentioned in Section 3.5.1, literature confirms the presence of two major aquifer systems in the area. The lower system (Yorktown Formation) is not confined at the QADSY. Clay was intercepted at the base (20 feet) at SW-4 but not in any of the deeper borings, including wells DW-1 through DW-8. The confining bed between the Columbia and Yorktown aquifers does not exist at the site; it appears to be eroded from channelization and meandering of the Elizabeth River. The Yorktown aquifer is not hydraulically separated from the Columbia aquifer at the site.

The Yorktown aquifer in the area of the site is only used for lawn irrigation. The discharge flows to either the Elizabeth River or Willoughby Bay. This aquifer is not used for public water supply because the downgradient surface waters (Willoughby Bay and Elizabeth River) are brackish and contain high metal concentrations.

The Yorktown and Columbia aquifers are hydraulically connected at the site, producing an unconfined aquifer. Aquifer thickness has not been determined at the site, but appears to be

between 85 to 140 feet by incorporating the fill (15 to 20 feet) and Tabb (20 feet) and Yorktown (50 to 100 feet) formations (Meng and Harsh, 1988).

Groundwater in the study area is sustained by precipitation, which infiltrates the land surface, and by regional flow. Broadly speaking, the unconfined aquifer is recharged by infiltration.

Recharge by infiltration at the site and surrounding areas is limited to unpaved areas; extensive paved areas and man-made drains and culverts control much of the surface runoff. The construction and placement of the drainage network may also have profound effects on the localized flow in the area: they may be partially permeable and intercept the groundwater surface.

Annual precipitation averages 47 inches; however, much may be lost as runoff to man-made drainage ways. Additionally, evapotranspiration may result in a significant loss, despite the lack of vegetation at the site. The annual recharge to the water table aquifer is not precisely known, but is estimated to be between 12 and 20 inches.

Groundwater discharge from the unconfined aquifer is thought to be primarily into Elizabeth River to the west and Willoughby Bay to the east. However, significant control on groundwater discharge and flow patterns (Section 3.6.2) may be exercised by man-made drainage culverts that may intercept the water table.

### **3.6.2 Groundwater Movement**

Regional steady-state groundwater flow directions (i.e., across the area occupied by the base) remain undetermined but would be expected to be northwest, following topography. However, because the base is almost completely surrounded by tidal water bodies (the Elizabeth River, Hampton Roads, Willoughby Bay, Masons Creek, and Lafayette River), which are the likely groundwater discharge areas, recharge undoubtedly results in a more complex flow pattern.

Onsite flow has been assessed from liquid level data collected from the monitor wells installed at the site during the field investigation. Only data from the shallow wells are used to evaluate the flow in the water table aquifer. The liquid levels are included in Appendix E.

The water table across the site ranges between 3 and 5 feet above msl; the water table gradient, thus flow direction, is generally to the west across the site (Figure 3-4). It is likely that seasonal fluctuations and man-made drainage influence the flow of shallow groundwater. However, the development of a contaminant plume to the west of the most impacted part of the site (Section 4.0) indicates that flow to the west predominates.

Horizontal gradients in the water table aquifer across the site were calculated by dividing the head difference between two points on a flow line (perpendicular to a contour line) by the



horizontal distance between those points. Ideally, measurements between exact points (monitor wells) are used. No two monitor wells are located exactly along a flow line at the QADSY. Consequently, the hydrostatic heads and horizontal differences were taken from the groundwater gradient maps for 5 October 1990, 29 January 1991, and 19 January 1993. Three values were taken from each map corresponding to the north, central, and southern portions of the site. A mean value for the horizontal hydraulic gradient was then calculated. The mean value for 5 October 1990 was 0.00086 ft/ft, for 29 January 1991 was 0.00076 ft/ft, and for 19 January 1993 was 0.0006 ft/ft. Horizontal gradient changes can greatly influence the groundwater velocity within the aquifer.

Vertical hydraulic gradients are calculated using water elevations from adjacent wells screened at different intervals within the aquifer using the following formula:

$$i_{\text{vert}} = \frac{h}{l}$$

where  $i_{\text{vert}}$  = vertical hydraulic gradient (ft/ft)  
 $h$  = head difference noted in the two wells  
 $l$  = vertical separation distance, the mid-elevation of the screened area in the shallow well minus the mid-elevation of the screened area in the deep well

The vertical gradients were calculated at nested locations SW-8/DW-2 and SW-2/DW-1 from elevations taken on 5 and 17 October 1990, 20 March 1991, and 19 January 1993 and at nested location SW-9/DW-5 from elevations taken on 19 January 1993. Calculations are summarized in Table 3-1.

Positive readings indicate a downward or "normal" gradient exists; negative readings indicate an upward gradient. The values obtained range from 0.006 to 0.038 ft/ft.

An upward gradient was noted in both nested well locations on 17 October 1990. This may indicate that the aquifer is subject to fluctuations in pressure over time. The reason for this is not known.

The average linear flow velocity through the aquifer was calculated using the following formula:

$$v = \frac{ki}{n}$$

where      v = flow velocity  
             k = hydraulic conductivity  
             i = horizontal gradient  
             n = effective porosity

Hydraulic conductivity data were generated from the pump test data and in-situ hydraulic conductivity (slug) tests carried out at the site; an average value of 17 ft/day was used. Horizontal gradient data are taken from the values calculated earlier in this section. Effective porosity was calculated from sieve analysis data.

Based on the data available, the average linear velocity of the groundwater beneath the QADSY is approximately 23 feet per year. A groundwater contour map (Figure 3-4) illustrates the flow direction at the site as determined by liquid levels. A groundwater water divide located at the western boundary of the QADSY displays groundwater flows from the site toward the Elizabeth River. Monitor wells DW-2, DW-4, GW-4, and SW-8 are located east of the groundwater divide and are considered background wells because they are not hydrologically connected to the QADSY wells.

**Table 3-1. Vertical Component Hydraulic Gradients  
at the QADSY**

Date	Well	Water Elevation Above MSL	Well	Water Elevation Above MSL	h (ft)	l (ft)	Vertical Gradients (ft/ft)
10/5/90	SW-2	2.87	DW-1	2.47	0.4	22.5	0.017
10/5/90	SW-8	2.90	DW-2	2.41	0.49	21.5	0.023
10/17/90	SW-2	2.72	DW-1	2.81	-0.09	22.5	-0.004
10/17/90	SW-8	2.73	DW-2	2.81	-0.08	21.5	-0.004
3/20/91	SW-8	2.58	DW-2	2.45	0.13	21.5	0.006
1/19/93	SW-10	3.35	DW-6	3.24	0.11	15	0.007
1/19/93	SW-9	4.29	DW-5	4.12	0.17	15	0.011
1/19/93	SW-2	5.20	DW-1	4.41	0.79	22.5	0.035
1/19/93	SW-8	5.19	DW-2	4.33	0.86	22.5	0.038

		NORTH CAROLINA			VIRGINIA			
SYSTEM	SERIES	STRATIGRAPHIC UNITS	HYDROGEOLOGIC UNITS		STRATIGRAPHIC UNITS	HYDROGEOLOGIC UNITS	DESCRIPTION OF HYDROGEOLOGIC UNITS	
QUATERNARY	RECENT PLEISTOCENE	POST-MIOCENE (UN-DIFFERENTIATED)	WATER TABLE OR QUATERNARY AQUIFER		TABB	FILL	WATER TABLE OR COLUMBIA AQUIFER	Unconsolidated sand, silt and some gravel. Sand units yield quantities adequate for domestic and small industrial demands, used extensively for lawn watering. Unconfined aquifer.
						LYNNHAVEN MEMBER		
TERTIARY	UPPER	YORKTOWN PUNGO RIVER	TERTIARY AQUIFER SYSTEM	SAND AQUIFER	CHESAPEAKE GROUP	YORKTOWN	YORKTOWN AQUIFER	Sand and shell beds main water-bearing units. Adequate for moderate public and industrial supplies. Artesian
	MIDDLE					CALVERT	CONFINING UNITS	
	EOCENE	CASTLE HAYNE LIMESTONE		LIMESTONE AQUIFER		NANJENDY	NOT FOUND IN STUDY AREA	
	PALEOCENE	BEAUFORT				MATTAPONI	EOCENE-UPPER CRETACEOUS AQUIFER	Glaucconitic sand and interbedded clay and silt. Infrequently used as a water supply. Yields adequate for moderate supplies. Brackish in most of area. Artesian
CRETACEOUS	UPPER	PEEDEE BLACK CREEK UNNAMED	CRETACEOUS AQUIFER SYSTEM	UPPER UNIT	LOWER CRETACEOUS	TRANSITIONAL BEDS	LOWER CRETACEOUS	Interbedded gravel, sand, silt, and clay. Yields are adequate for large industrial use. Brackish in most of area. Artesian
	LOWER	LOWER UNIT		PATUXENT				



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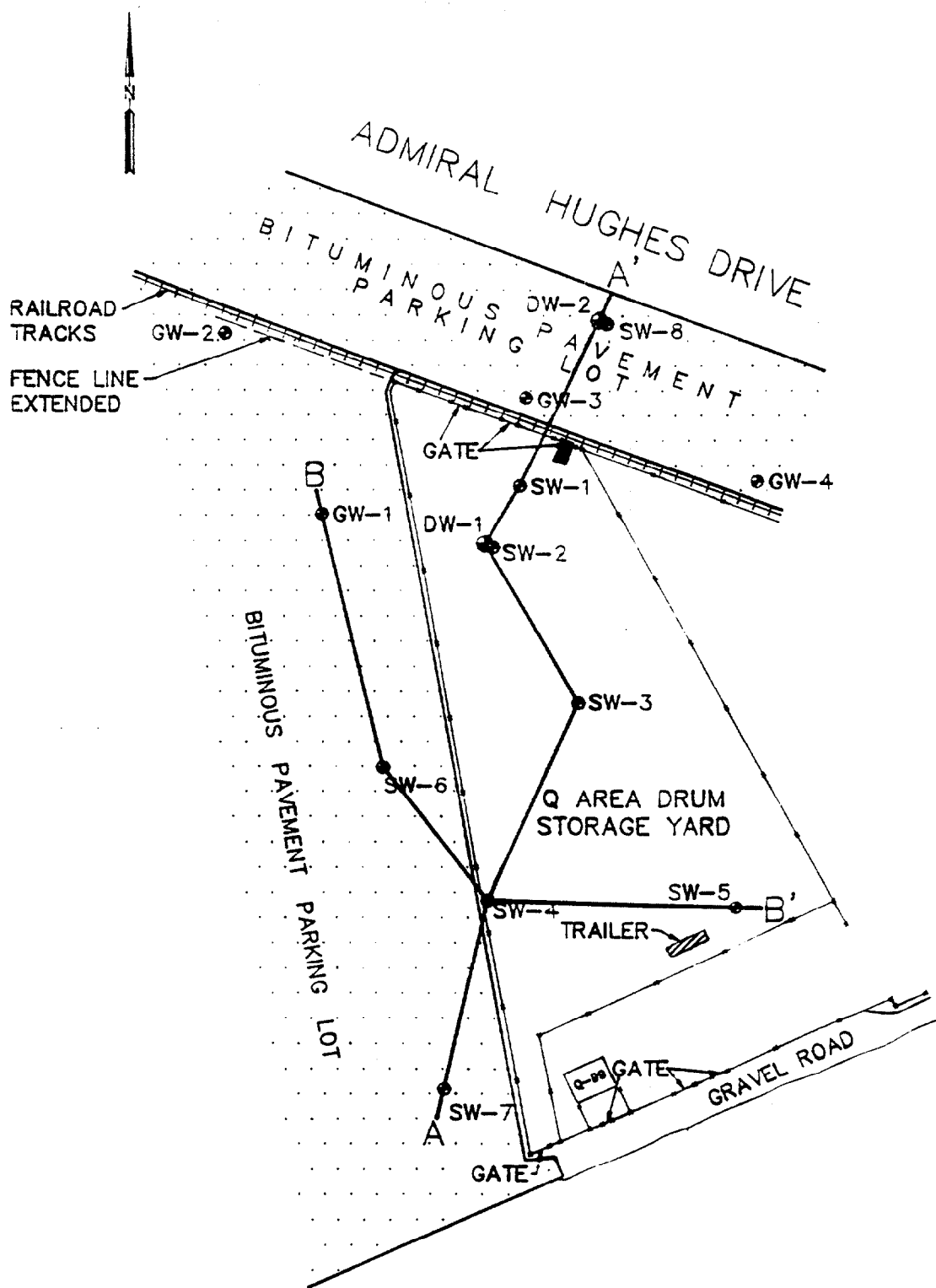
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3-1 / 1

TITLE  
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SOUTHEASTERN VIRGINIA (FROM SIUDYLA, ET AL., 1981)  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
NAVFAC - Q AREA

FIGURE  
3-1



MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

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GEOLOGICAL SECTION LOCATIONS  
Q AREA DRUM STORAGE YARD  
NORFOLK, VA

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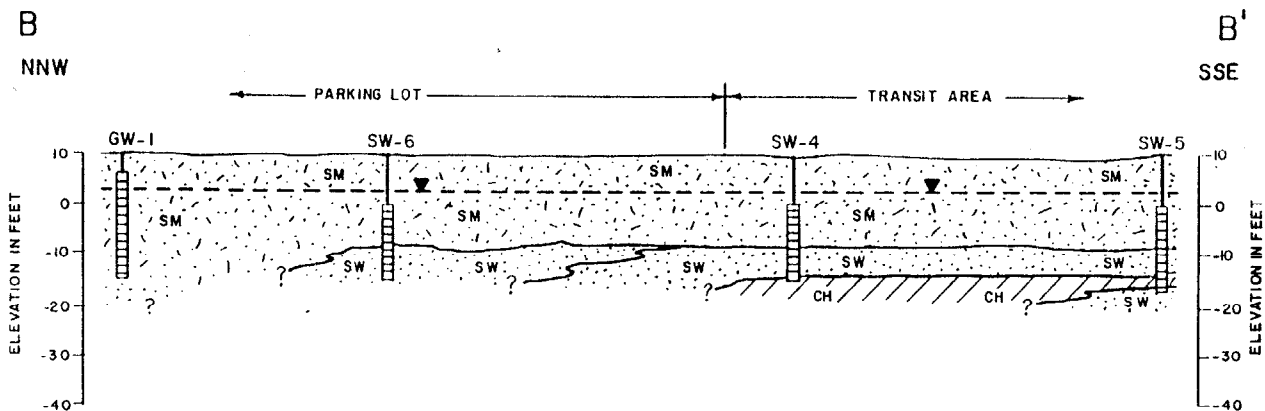
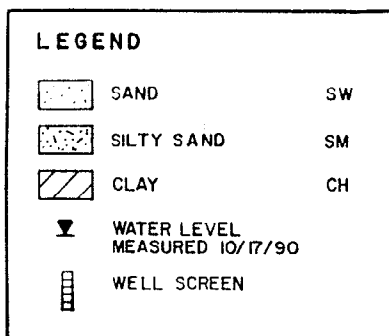
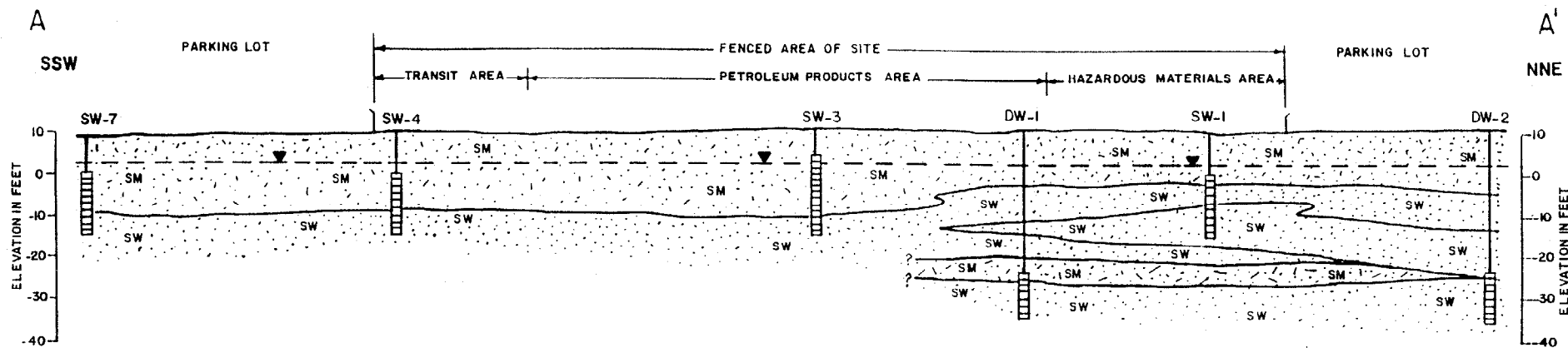
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FIGURE

3-2

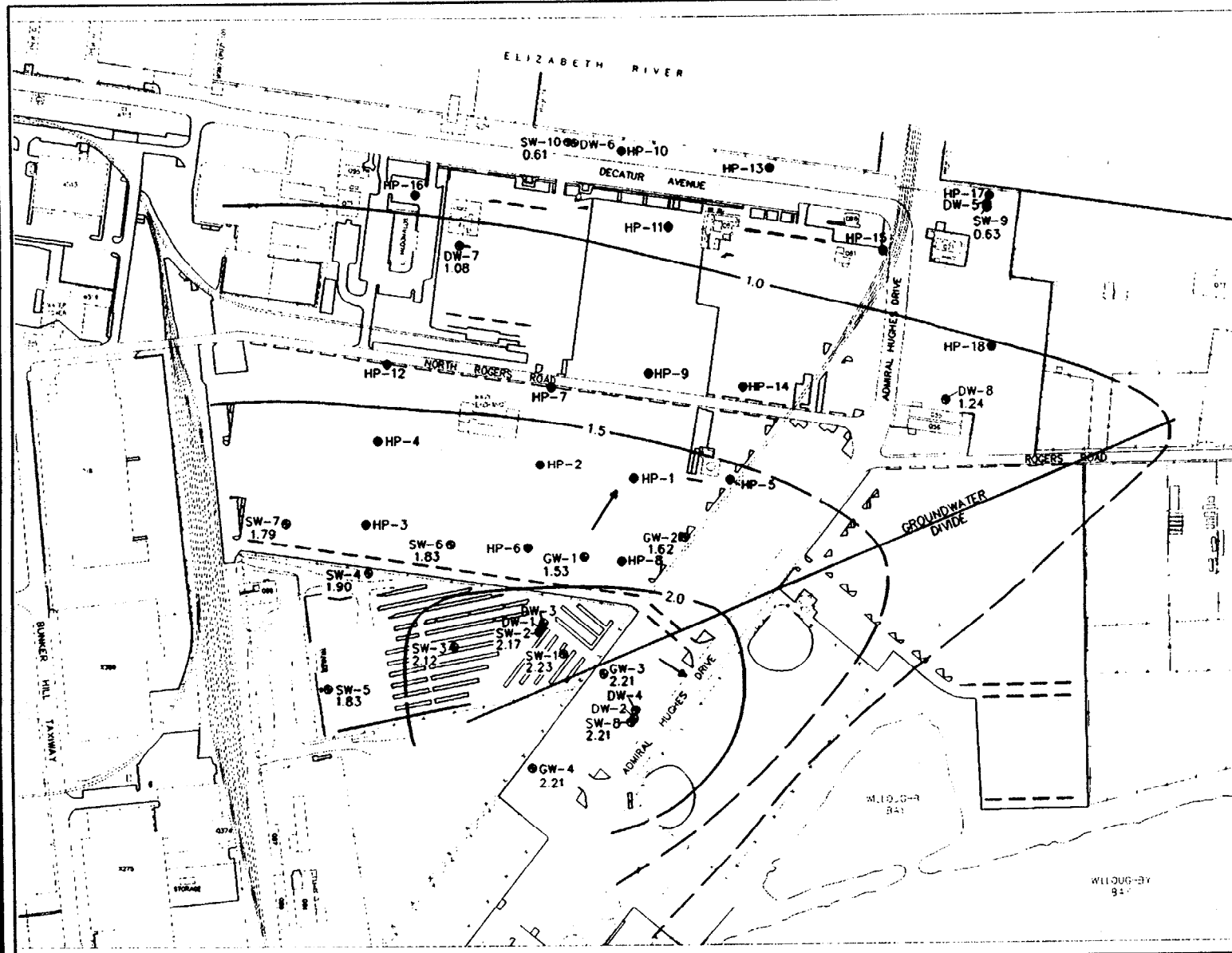


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DRAWN BY <b>LAF</b>	APPROVED BY		
JOB NO. <b>4901107</b>	DWG. NO. / REV. NO. <b>2 -</b>	CLIENT <b>LANTNAVFACENGCO</b>	FIGURE <b>3-3</b>



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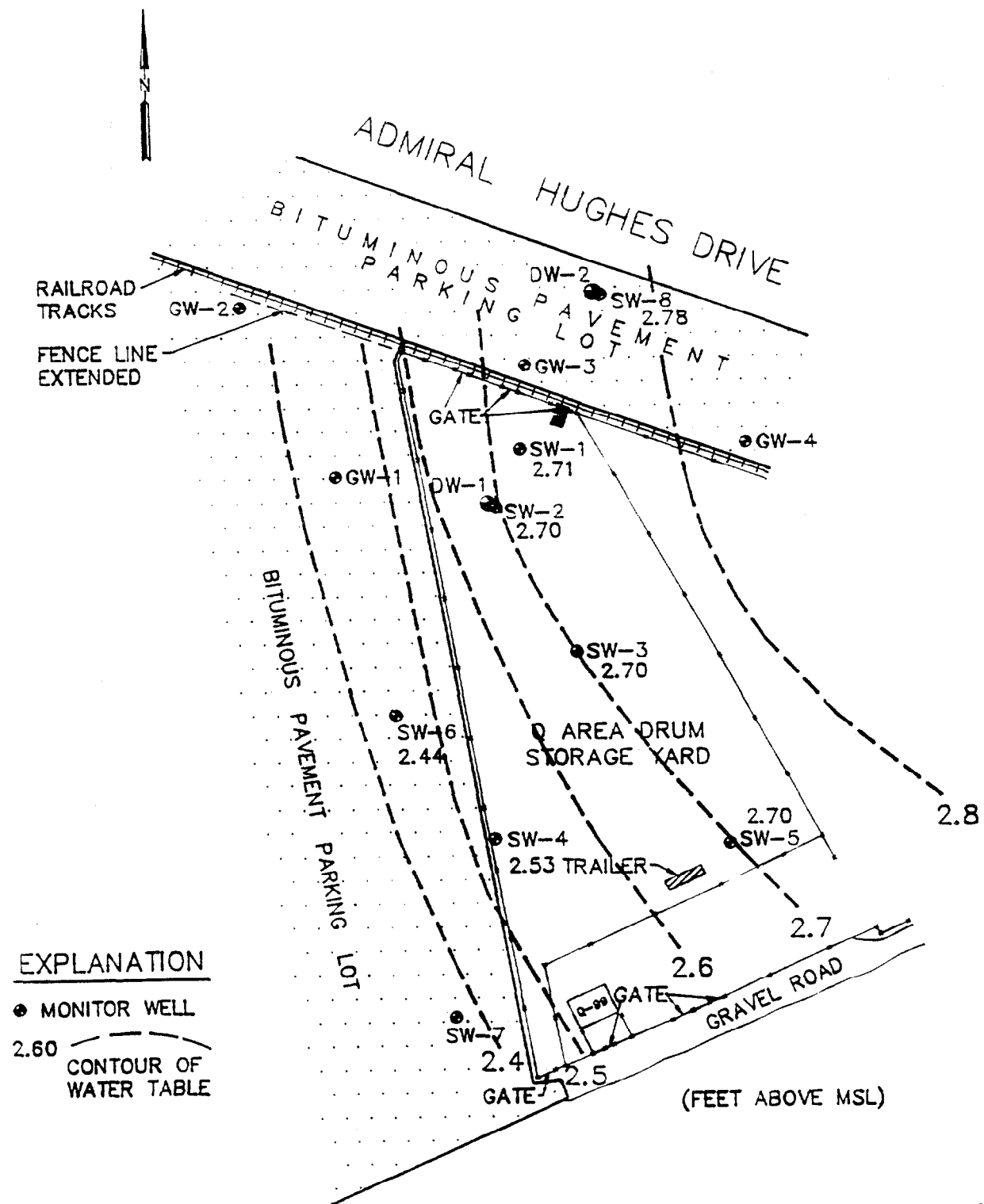
GROUNDWATER CONTOUR MAP  
JANUARY 19, 1993  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT

NAVFAC - Q AREA

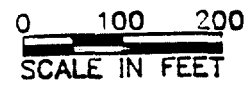
FIGURE

3-4



MAP SOURCE:  
PLAT MAP DRAWN BY  
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DATED FEBRUARY 22, 1991.

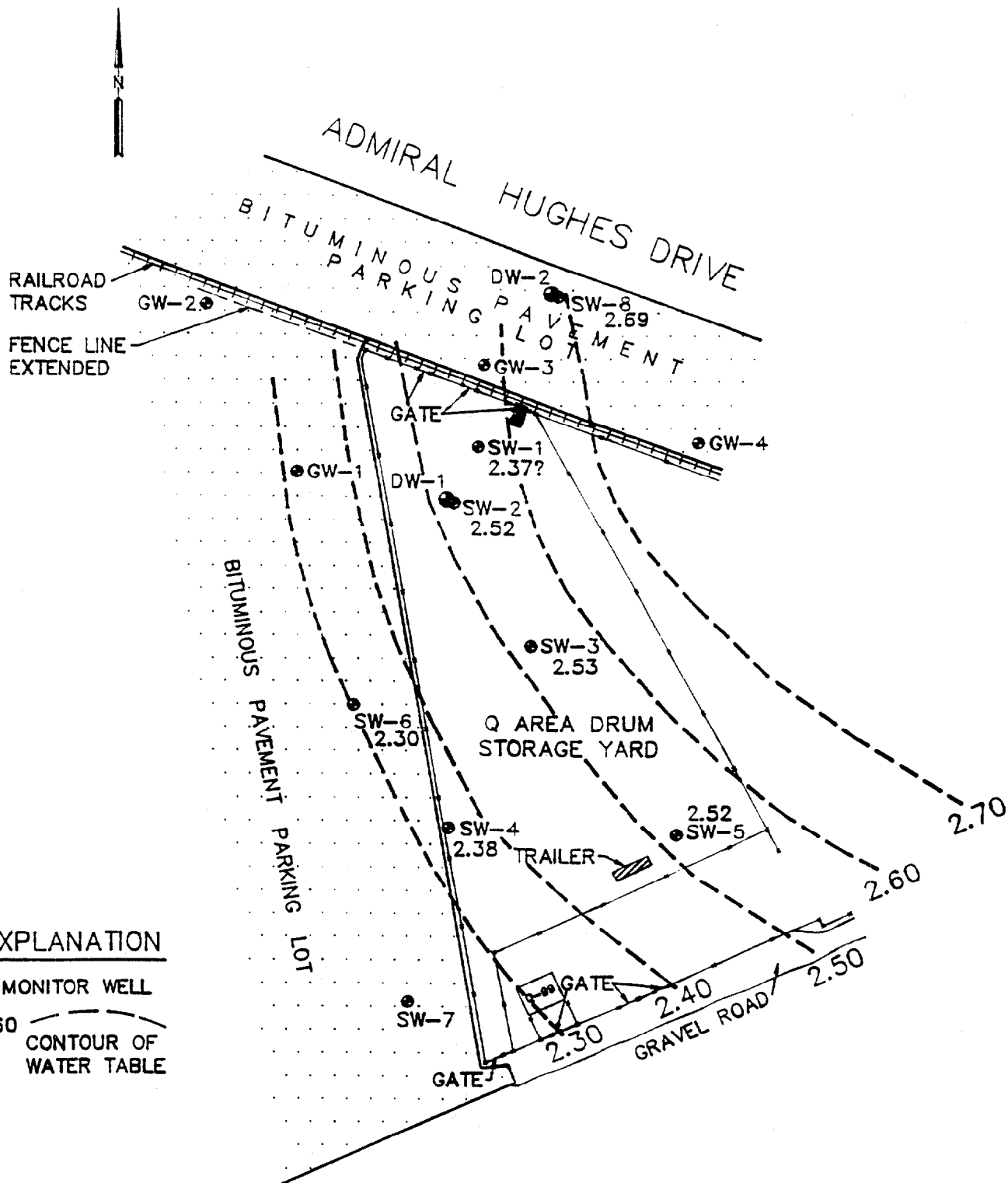
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DATE 3-12-91	SCALE SHOWN	TITLE GROUNDWATER CONTOUR MAP JANUARY 29, 1991 Q AREA DRUM STORAGE YARD, NORFOLK, VA
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JOB NO. 4901107	DWG. NO./ REV. NO. GW1-91/-	CLIENT LANTNAVFACENGCOM
		FIGURE 3-5





# EXPLANATION

- MONITOR WELL
- 2.60 ——— CONTOUR OF WATER TABLE

MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

BLDG. X-218 IN THIS VICINITY

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GROUNDWATER CONTOUR MAP  
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Q AREA DRUM STORAGE YARD, NORFOLK, VA

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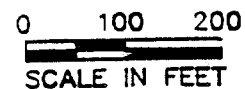
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FIGURE  
3-6



## 4.0 AQUIFER TESTING AND GROUNDWATER MODELING

This section includes the procedures and results of the aquifer testing studies. Continuous water level monitoring was conducted for one lunar cycle to define tidal and recharge influences on the potentiometric surface. Results are included in this section. An analysis of the vertical relationship between the groundwater and surface water is also included. The data from a 72-hour aquifer drawdown and slug tests were included in the groundwater flow model, which was developed to simulate contaminant transport at the site.

### 4.1 Aquifer Pump Test

A 72-hour aquifer pump test was conducted between 29 January and 1 February 1991 to provide parameters such as hydraulic conductivity (K), transmissivity (T), and specific yield ( $S_y$ ). The pump test involved withdrawing groundwater from monitor well SW-3 at the maximum sustainable yield of the well. This induced a drawdown in the pumping well and in surrounding observation wells, which was recorded with Envirolab dataloggers and pressure transducers.

Prior to initiating the pump test, static groundwater water levels were monitored for 24 hours to observe background conditions at the site. Data for the static levels and pump test were recorded using pressure transducers connected to an eight-channel data logger. The pre-test also examined the dependability of the pressure transducers.

A large tidal influence was observed at the site, and fluctuation in each well was not constant. Manmade drainage ways may allow tidal recharge at a greater rate than if the aquifer was recharged naturally. Tidal fluctuations in excess of 0.2 foot were not uncommon.

SW-3 was pumped for 72 hours at a constant rate of 5.2 gpm creating a drawdown of approximately 10 feet. The water levels were recorded in six monitor wells (SW-1, SW-2, SW-4 through SW-6, and SW-8) and the recovery well (SW-3) for the duration of the pump test. The locations are shown on Figure 4-1. After the test was complete, groundwater levels were recorded for an additional five hours to evaluate aquifer recharge. Groundwater level measurements of the six observation wells were recorded and plotted in Figures 4-2 through 4-7. Due to the large tidal influence, a mean value for the water level had to be calculated from the water level graphs.

Although the six observation wells appeared to show a groundwater drawdown, the wells did not appear to recover when pumping ceased. The maximum drawdown versus distance from the pumping well for each of the observation wells is presented in Table 4-1. A correlation is apparent between the drawdown and the distance of each observation well from pumping well SW-3: the closer the observation wells, the greater the drawdown observed. The relationship does not hold true for observation wells SW-2 and SW-5.

The data were inserted into AQTESOLV® (a hydraulic software package for time versus drawdown in confined and unconfined aquifers, developed by Geraghty & Miller, Inc.) under the assumption that an unconfined aquifer is present beneath the QADSY. The results showed T at 3000 sf/day and K at 24 ft/day. The specific yield ( $S_y$ ), also appears to be representative of the aquifer with a value of 0.0317. Because K and T do not appear to accurately represent the aquifer, ESE conducted slug tests on SW-1, SW-2, and SW-4 through SW-8 to further evaluate T and K values to be input into the groundwater model.

## 4.2 Aquifer Slug Test Results

Slug tests performed on 20 March 1991 were used to determine aquifer hydraulic conductivity. Only recovery is recorded during this test, so it does not rely on observing drawdown in monitor wells. This is particularly useful in cases where the hydraulic conductivity is low or monitor wells are a distance from the pumping well (as is the case at the QADSY).

The slug tests were performed by displacing a known volume of water (approximately 1 gallon) from each of the shallow 2-inch observation wells (SW-1, SW-2, and SW-4 through SW-8) and recording groundwater recovery level over time. Groundwater data were plotted in semilog plots of time versus drawdown to calculate K and T for the groundwater model (Figures 4-8 through 4-14).

The Bouwer and Rice (1976) method is currently the best method for interpreting data acquired from slug tests. This method appears most applicable for the unconfined aquifer found at the QADSY, where the well is surrounded by a sand pack and the screened interval is above the groundwater surface. However, comparable results have been obtained using the Hvorslev method (1951).

The slug test basic theory dictates that there is an exponential decrease (or increase) in drawdown during a slug test as a function of time. Thus, a plot of the logarithm of drawdown versus time should yield a straight line that is a direct function of the hydraulic conductivity (Hvorslev, 1951). In practice, however, a significant departure from linearity generally occurs after a short time interval due to the effects of the sand pack and other factors (Bouwer and Rice, 1976). Consequently, it is critical that accurate and precise data are acquired at the beginning of a slug test. Calculations of K and T are found in Section 4.3.

## 4.3 Bouwer and Rice Method

The basic equation for evaluating time-drawdown data with the Bouwer and Rice method is:

$$K = \frac{r_c^2 \ln (Re/r_w)}{2 L_e} \quad \frac{1}{t} \ln \frac{y_0}{y_t}$$

Where:  $K$  = hydraulic conductivity

$r_c$  = radius (feet) of the well casing

$L_e$  = length of screened interval (feet) below the groundwater surface

$t$  = time (minutes)

$R_e$  = effect radius

$r_w$  = horizontal distance

$y_0$  = drawdown at time zero

$y_t$  = drawdown at time  $t$

The value for the dimensionless parameter  $\ln(R_e/r_w)$  obtained from Bouwer and Rice is essentially a function of the screened interval ratio to the sand pack radius. In the absence of other information, ESE has assumed the saturated aquifer thickness is 50 feet, 5 feet below the deepest well drilled. Choosing a saturated thickness greater than the well screened interval decreases the value of  $\ln(R_e/r_w)$ , and therefore the hydraulic conductivity. The value of  $r_c$  (0.083 foot) is modified according Bouwer's (1989) discussion to account for the sand pack radius around the well casing. A porosity of 0.3 was assumed for the sand pack.

The hydraulic conductivity was calculated using the parameters from the equation and the slope of the line through the initial data. The result is a value of  $K$  and the transmissivity ( $T$ ), assuming a saturated thickness ( $b$ ) of 50 feet.  $T$  is calculated from the equation  $T=Kb$ . Hydraulic conductivity and transmissivity data calculated from the slug test are included in Table 4-2.

#### 4.4 Aquifer Test Conclusions

Regional information from the USGS WRI Report 87-4240, page 37, lists the summary of horizontal hydraulic conductivities and transmissivity values for the different aquifers. The median values for the Columbia Group range from 8.3 to 28.7 ft/day, and the median values for the Yorktown aquifer range from 4.1 to 23.1. The 10.9 ft/day value for hydraulic conductivity used in the model is acceptable for both the Columbia and Yorktown aquifers.

A constant rate pumping test is the most valuable tool to determine aquifer characteristics, although the data can produce unreliable results. It is the professional judgement of the hydrogeologist to determine if the calculated results of the constant rate pumping test are within an acceptable range compared to regional data. In some instances, results from the constant rate pumping tests can be influenced by outside factors. Attempts can be made to account for the outside influences, but this can also lead to unreliable results. The initial calculations made from the constant rate pumping test resulted in values that were unacceptable compared to the literature values in the USGS report. When constant rate pumping tests are not reliable, slug test calculation or regional values can be used as initial aquifer parameters in groundwater flow models.

The constant rate pumping tests and slug tests are used to obtain aquifer parameters, which are used as input parameters to groundwater flow models. Slug tests have limitations, but can provide acceptable information when the results of a constant rate pumping test are unacceptable.

## 4.5 Tidal and Recharge Influences

Continuous water level data were collected at monitor wells DW-1 and SW-1 between 9 December 1992 and 12 January 1993. The data from the shallow monitor well (SW-1) contained extensive influence from precipitation and was rendered unreliable. However, SW-1 remained relatively stable when not being influenced by precipitation. In addition, the water level in SW-1 remained higher than DW-1 except during the spring tides at the beginning and end of the study. Water elevation data from DW-1 exhibited well-defined semidiurnal periodicity (Figure 4-15).

Additional, simultaneous water level data from the National Oceanic and Atmospheric Administration (NOAA) tide station at Sewells Point were obtained for comparison. Plotting the two water level signals indicate a distinct correlation (Figure 4-16). An ESE-developed computer program for cross-correlating two signals at different phase-lag was run on the two data sets from Sewells Point and monitor well DW-1. The program was run based on changing the offset of the two time-series data sets at 5-minute increments. The program then calculated the Pearson Product correlation coefficient between the two curves in the portions of each curve which overlap. For example, for two identical curves, maximum correlation will occur at a zero offset. For a sine and cosine curve, maximum correlation will occur at a 90-degree phase lag. The results of the two data sets analyzed indicate that a maximum correlation occurs when the tide signal is advanced 50 minutes. This indicates that the peak groundwater potentiometric level occurs approximately 50 minutes after high tide. Groundwater time lag is illustrated in Figure 4-16.

Head differences were also calculated for the two data sets. The difference in elevation between Sewells Point tidal values and DW-1 were calculated. Positive values represent tidal elevations higher than groundwater elevations. A mean value of -1.9 feet resulted for the month of data, suggesting a net negative influence of the tide on the groundwater at the site and a net positive gradient toward the Elizabeth River and Willoughby Bay. The effect would be to allow dispersal of the local groundwater to the surrounding surface water. Gradient magnitudes depend on the proximity of the local water body and the phase of the tide. Assuming a minimum distance to Willoughby Bay of 900 feet to the southeast and the mean hydraulic head of 1.9 feet, the gradient is 0.0021.

## 4.6 Vertical Flow Regime

An additional data set consisting of the tidal heights and a piezometer installed in the submarine sediments were collected from 13 to 22 January 1993 (Figure 4-17). The potentiometric head difference of the surface water to the piezometer height was very low, as illustrated on Figures 4-18 and 4-19. The significance of this difference is difficult to ascertain. Because there were no simultaneous groundwater data with which to compare this, it is impossible to determine a temporal relationship. It can be assumed, however, based on the seaward gradient and piezometer/river head difference, that the local groundwater is discharging into the surrounding surface waters.

Seepage discharge can be estimated using Darcy's equation:

$$Q = KiA$$

where:

- Q = flow volume
- K = hydraulic conductivity (11 ft/day)
- i = horizontal gradient (0.0021 ft/ft)
- A = cross-section area of aquifer (96,000 ft<sup>3</sup>)

The following assumptions were made to calculate discharge:

- 1) Darcy assumptions were employed.
- 2) The thickness of the aquifer was calculated by the aquifer thickness (110 feet) subtracted by the height of the bulkhead (50 feet).
- 3) Leakage of the bulkhead is insignificant.
- 4) The length of the aquifer is the attached impacted area that is between Pier 11 to 500 feet north of Pier 12. The approximate discharge is 2200 ft<sup>3</sup>/day or 16,600 gallons/day.

## 4.7 Groundwater Flow Model Development (MODFLOW)

The model domain comprises the area depicted in Figure 4-1. The area is bounded by the Elizabeth River on the west, Willoughby Bay on the east, and Bunker Hill Taxiway on the south. The flow system has been conceptually characterized as a two-layer system separated by a semiconfining layer. A uniform grid was constructed over the model domain. Model input included boundary conditions to represent the Elizabeth River, the bulkhead along the Elizabeth River, Willoughby Bay, and recharge to provide a water source for the model.

#### **4.7.1 Model Grid**

The model domain grid was divided into 34 columns running east-west and 43 rows running north-south. A total of 2924 grid cells represented the model's two layers; the spacing between grid lines was a uniform 62.5 feet. The model covers approximately 4.9 square miles.

#### **4.7.2 Boundary Conditions**

Constant head boundaries were specified in the grid cells covering the Elizabeth River and Willoughby Bay in layers 1 and 2. The cells in these boundaries were set at constant head of 0.0 feet. A no-flow boundary was specified along the Elizabeth River to represent the bulkhead. The no-flow boundary representing the bulkhead was only used in layer 1, which represented the aquifer and flow system to the depth of the bulkhead (approximately 50 feet below msl). All other cells in the model domain were specified as active cells. In addition, the grids immediately west of the no-flow boundary bulkhead were also specified as active cells to allow for water movement on the river side of the bulkhead.

#### **4.7.3 Groundwater Recharge**

The only water entering the flow system is specified as recharge to layer 1. The source of the recharge is assumed to be from local rainfall. Previous studies have estimated recharge to the water table aquifer at approximately 10 to 15 inches per year (Hamilton, 1988). Recharge was specified as a heterogeneous matrix with an average over the model domain of 10 inches per year. The recharge matrix was established through the calibration process.

#### **4.7.4 Aquifer Parameters**

Site-specific aquifer parameters were calculated from a series of slug tests and constant rate aquifer performance test (APT). Aquifer parameters have also been established from regional information collected by the USGS (Hamilton, 1988). The site-specific and regional data were used as initial model input values for hydraulic conductivity and transmissivity. The values were adjusted during the calibration process to determine the appropriate values in MODFLOW. It is common in groundwater modeling to adjust the model values to calibrate the flow system. In this process, the professional judgment of the hydrogeologist is used to determine if the adjustments are reasonable.

Based on the calibration process, the hydraulic conductivity of layer 1 was set as a uniform value of 10.9 ft/day and the thickness was set at 50 feet. The calibrated transmissivity of layer 2 was 548 sf/day. The leakance value between layers 1 and 2 was set at 0.055 per day.



#### 4.7.5 Model Calibration

A potentiometric surface for the modeled area was established from the previous groundwater investigations. The elevation of this surface ranged from approximately 2 feet above msl in the vicinity of the QADSY to approximately 0.5 foot above msl near the Elizabeth River. The aquifer parameters and recharge values were adjusted in the calibration process to approximate the potentiometric surface of the water table. The calibration process resulted in a reasonable match of the potentiometric surface of the water table (Figure 4-20). The flow is generally to the northwest to the Elizabeth River and to the northeast to Willoughby Bay. MODFLOW output file is located in Appendix I.

### 4.8 Particle Transport Model Development Using INTERTRANS

The purpose of this exercise was to determine if the contaminants migrating from the QADSY to the bulkhead along the Elizabeth River will discharge to the surface water (Elizabeth River). ESE has developed a three-dimensional particle tracking solute transport model (INTERTRANS) that uses the potentiometric "heads" calculated from MODFLOW and tracks particles for a specified period of time. Because INTERTRANS is a three-dimensional model, it can depict both a map view and a cross-section view of the particle movement.

#### 4.8.1 MODFLOW Heads Conversion

Prior to using the particle tracking model, the heads generated from MODFLOW need to be converted to a format compatible for the particle tracking model. Because pumping is not involved in the simulation, the head distribution is the mechanism for the particle or contaminants to migrate. ESE has developed a conversion utility (CONMOD) to convert the heads generated from the MODFLOW output to a format suitable for use in INTERTRANS.

#### 4.8.2 Particle Tracking (INTERTRANS)

Particle movement from the contaminant source is a function of the groundwater head gradient and direction, the porosity of the porous media, and the dispersivity factor. In this task, the groundwater head gradient was supplied from the MODFLOW-converted heads. The typical porosity values for unconsolidated sands are between 25 and 50 percent. Laboratory values from soil samples taken during the hydrogeologic investigations were measured at approximately 25 to 30 percent. A value of 25 percent was used as an input parameter in INTERTRANS. The lower the porosity percent, the faster the particles move.

The dispersivity was set at 10 feet for the longitudinal, transverse, and vertical directions. A value of 10 feet was chosen as the dispersivity value, reasonable for alluvial sediments (Walton, 1988). The ratio between the longitudinal and transverse dispersivity values is usually 10:1; however, when a 10:1 ratio was used the particles migrated down with the groundwater gradient and all of the particles dropped below the bulkhead. In an attempt to be

conservative and allow for the particles to remain near the surface, the transverse dispersivity was set equal to the longitudinal value.

Two scenarios were conducted using continuous particle slugs. A continuous slug of 100 particles was placed within the boundary of the QADSY to model particle movement for approximately 40 years. The second scenario tracked a single particle movement for the same 40-year time frame.

### **4.8.3 Results of Particle Tracking**

The 40-year scenario indicated that particles will move horizontally downgradient to the northwest toward Pier 12 and the Elizabeth River bulkhead, dispersing horizontally and vertically to layer 2. The particles will reach the bulkhead and migrate down and under the bulkhead to the west of the river (Figures 4-21 and 4-22). Figure 4-21 depicts 100 particles traveling with the groundwater to the northwest, hitting the bulkhead, and continuing under the bulkhead and discharging in the river. Figure 4-22 depicts the same scenario using only one particle. The figure shows the particle traveling northwest to the bulkhead and then down and under the river.

## **4.9 Air Sparging/Soil Vapor Extraction (AS/SVE) Pilot Study**

### **4.9.1 AS/SVE Method**

Target Environmental Services conducted two AS/SVE pilot studies in May 1995. The pilot tests were performed at the HM and the FP areas. The purpose of the AS/SVE was to test the feasibility and obtain design data such as soil permeability and radius of influence for an AS/SVE system. Soil gas and groundwater samples, dissolved oxygen measurements, and groundwater levels were collected before, during, and after the AS/SVE pilot tests to measure the effectiveness of a potential AS/SVE system.

An air injection well, vapor extraction well, and monitor probes were installed at each site prior to the AS/SVE pilot studies (Figure 4-23). Specifics to the installation, field test procedures, and data collection are found in Target's June 1995 Final Report Soil Vapor Extraction/In-Situ Air Sparging Pilot Test.

### **4.9.2 AS/SVE Results**

Calculated air conductivities ranged from  $1.3 \times 10^{-6}$  to  $7.9 \times 10^{-8}$  cm<sup>2</sup> at the two sites. Permeability values are in the range from  $10^{-6}$  to  $10^{-10}$  cm<sup>2</sup> to be hydraulically conductive for remediation by vapor extraction.

The radius of vacuum influence ranges from 30 to 74 feet at the FP area to 21 to 37 feet at the HM area. The variations in the radius of influence appear to be from underground utilities causing variations in the soil permeability. The radius of air sparging influence ranges from 20 to 30 feet using screen located between 35 and 40 feet bgs. Increasing the

injection flow could increase the radius of sparging influence and VOC removal. Groundwater sample data indicated a decrease in VOC concentrations.

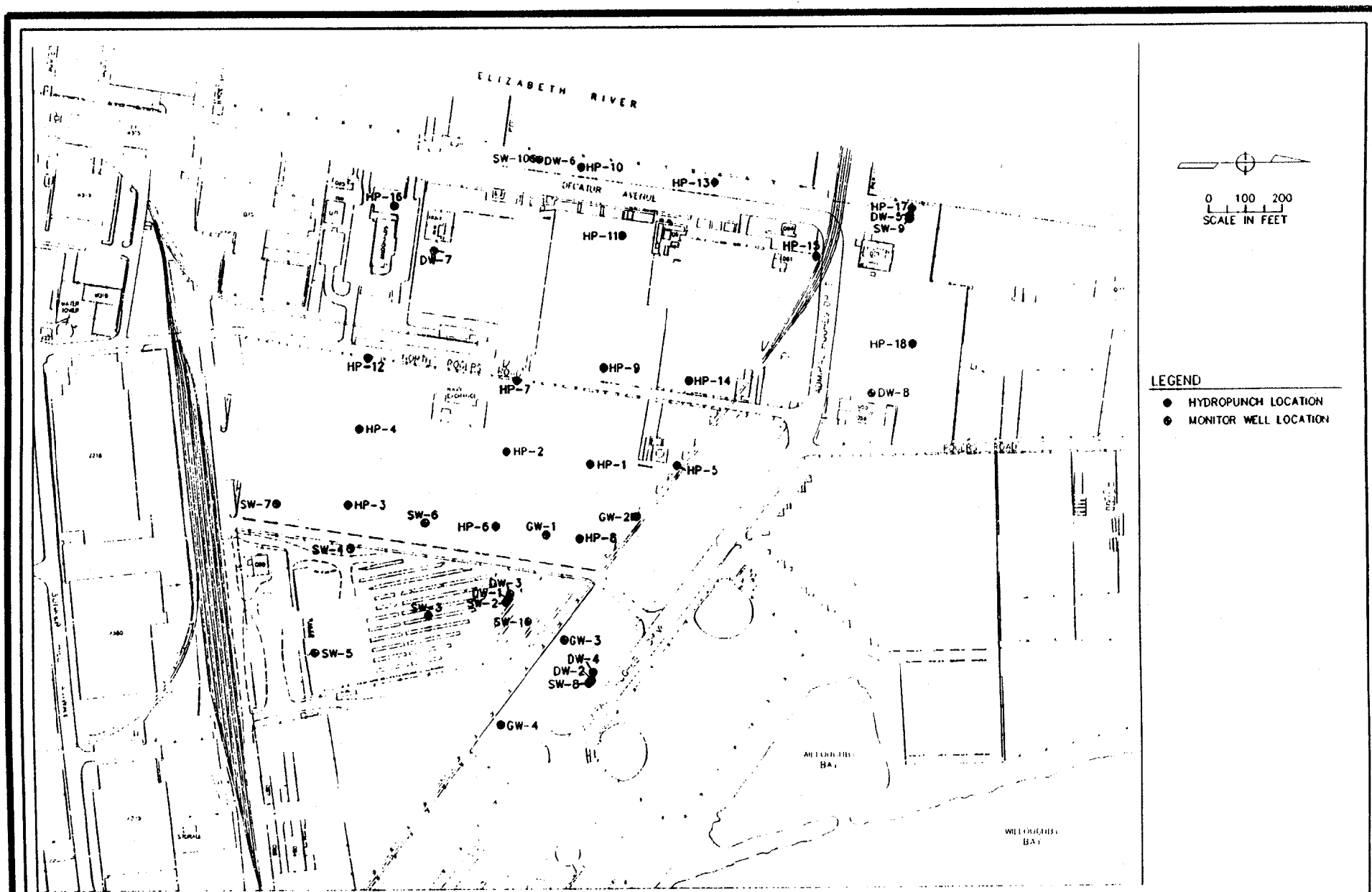
The increase of dissolved oxygen and groundwater potentiometric levels also indicated that AS/SVE is a feasible remediation technique at the QADSY. Specific information on the AS/SVE pilot studies such as concentration data and radius of influence graphs are located in Target (1995).

**Table 4-1. Drawdown of Observation Wells and Distance from Pumping Well SW-3**

Observation Well	Drawdown (feet)	Approximate Distance (feet)
SW-1	0.12	300
SW-2	0.12	200
SW-4	0.21	300
SW-5	0.14	320
SW-6	0.26	250
SW-8	0.09	570

**Table 4-2. Hydraulic Conductivity and Transmissivity Calculated from Slug Test Data**

	K (ft/day)	T (ft <sup>2</sup> /day)
SW-1	25.0	3125
SW-2	7.6	975
SW-4	10.5	1312
SW-5	10.5	1312
SW-6	6.0	750
SW-7	7.0	937
SW-8	9.0	1125
Average	11.0	1362



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DWG. NO./ REV. NO  
QDA / -

TITLE

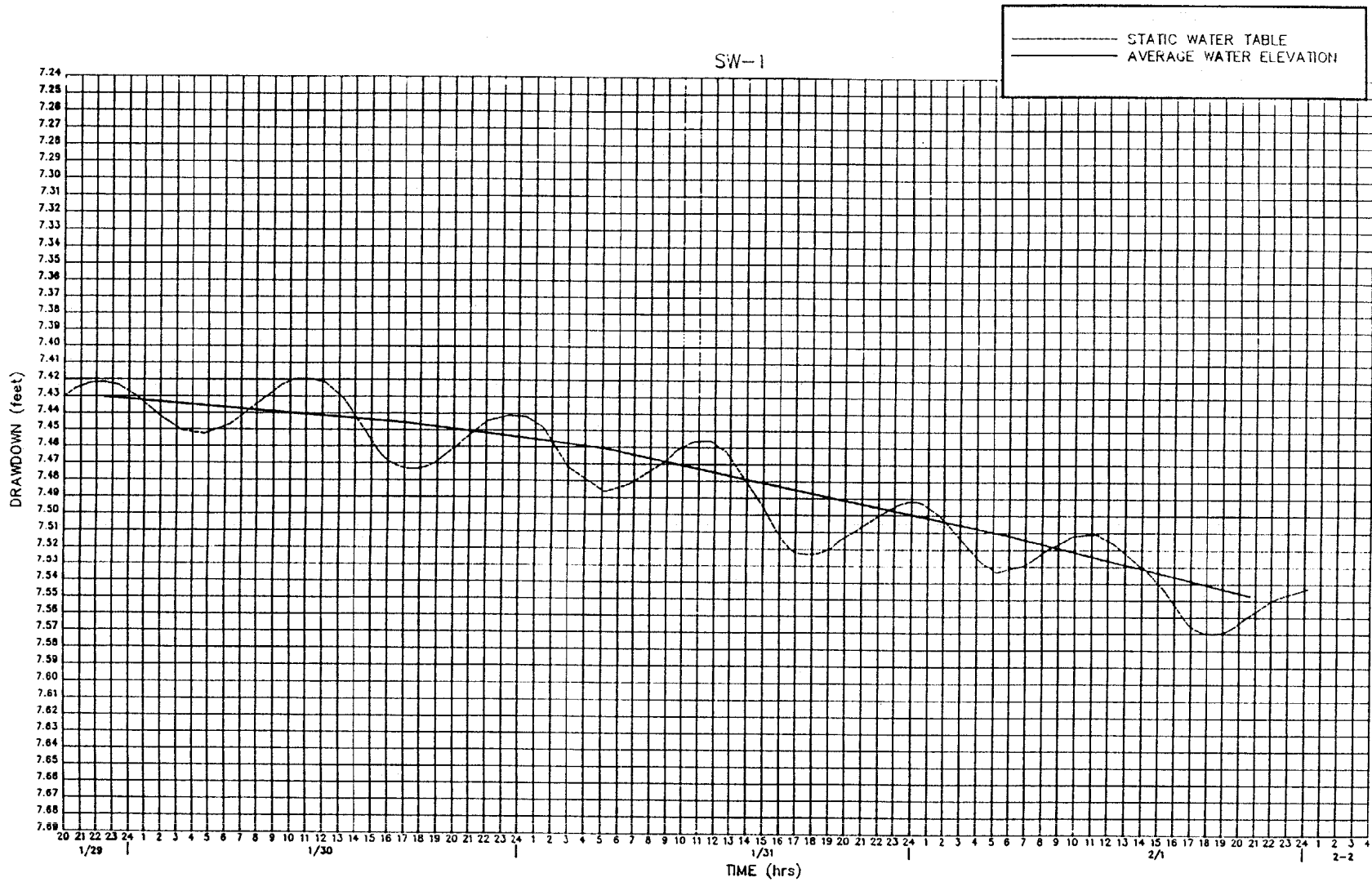
MONITOR WELL AND HYDRO-  
PUNCH  
LOCATIONS  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE 4-1

10 wells

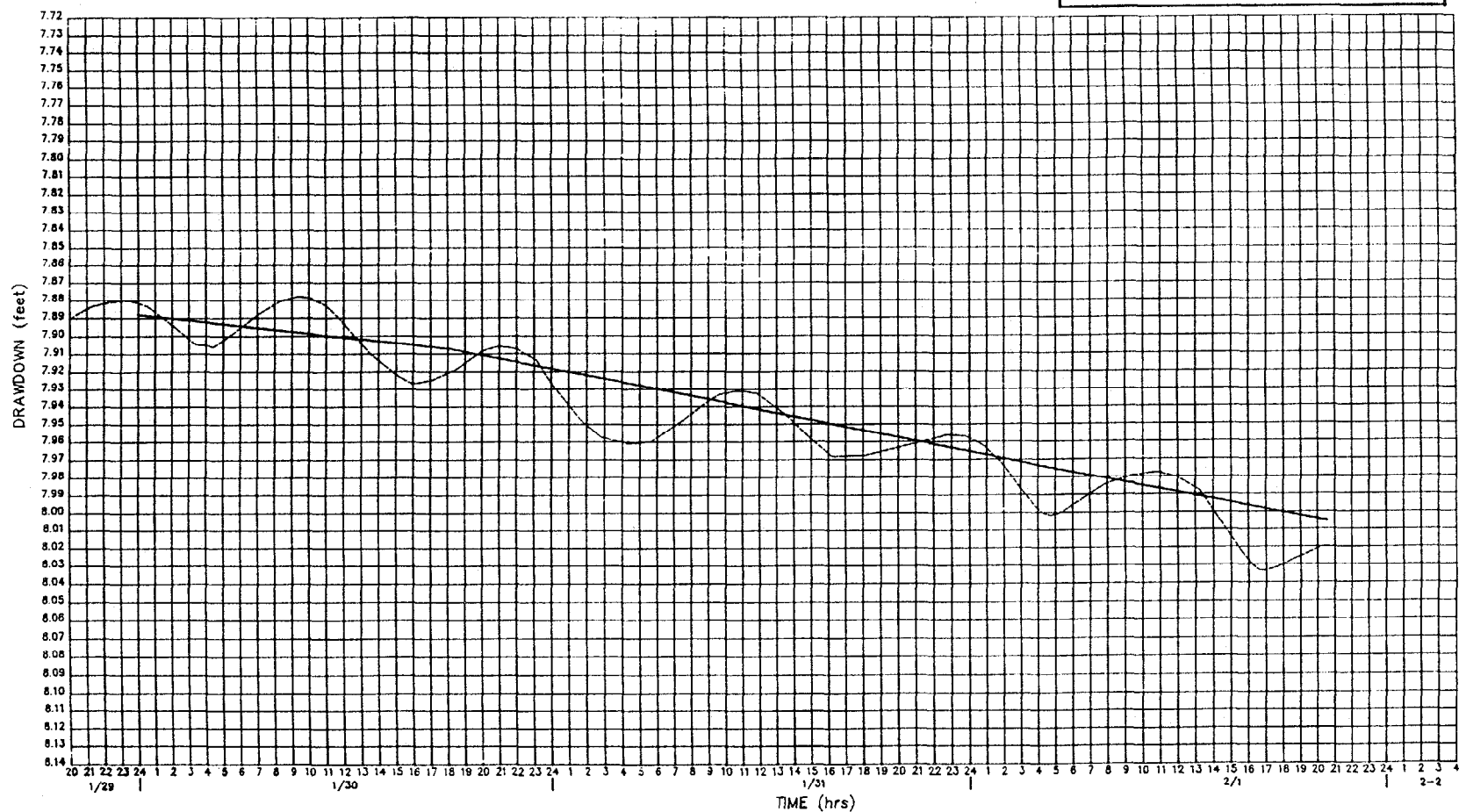


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DATE 5-23-91	SCALE SHOWN	TITLE OBSERVED GROUNDWATER DRAWDOWN	
DRAWN BY RG/LAF	APPROVED BY		
JOB NO. 4901107	DWG. NO./REV. NO. CHART 1 / 1	CLIENT LANTNAVFACENGCOM	FIGURE 4-2

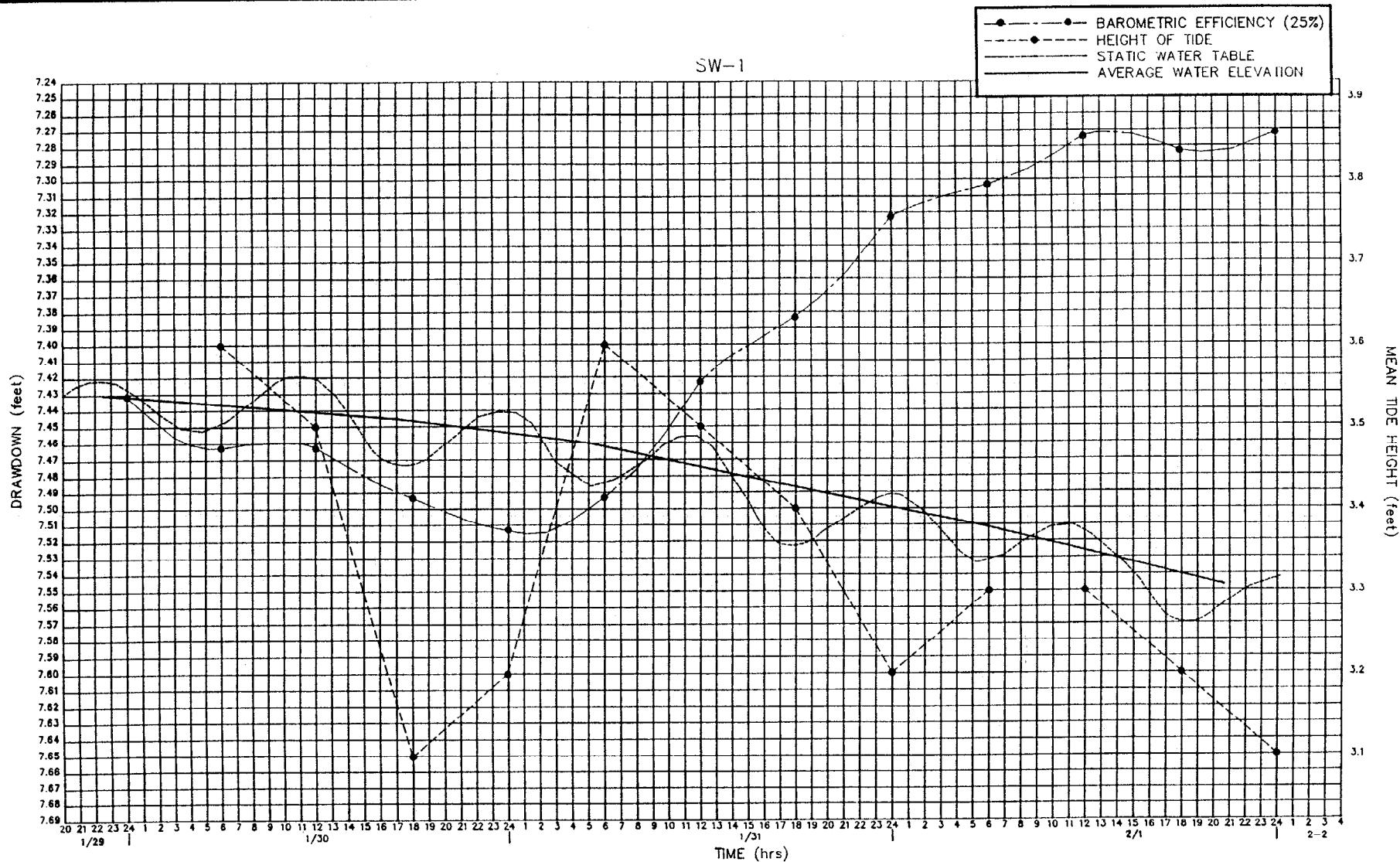
SW-2

——— STATIC WATER TABLE  
——— AVERAGE WATER ELEVATION



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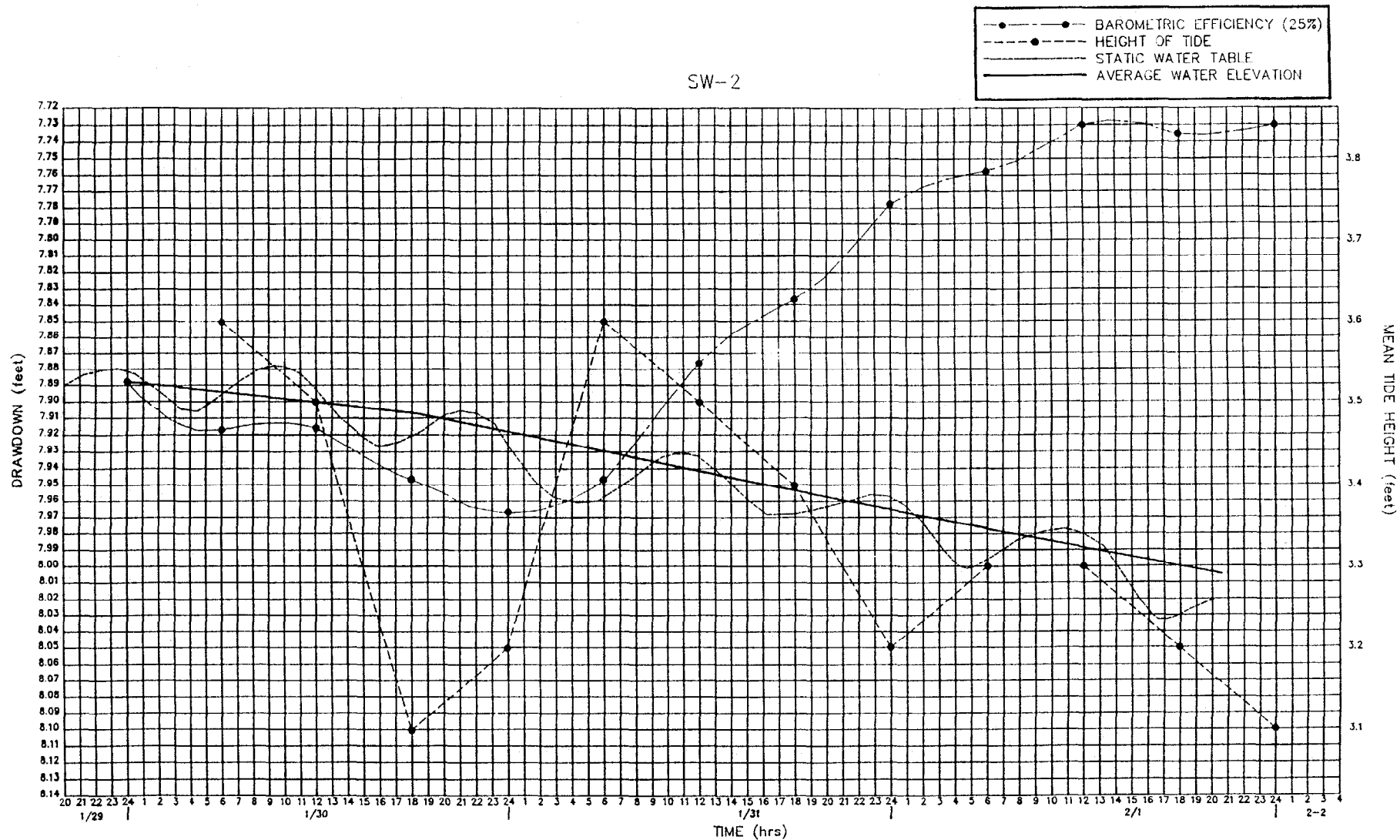
DATE 5-23-91	SCALE SHOWN	TITLE OBSERVED GROUNDWATER DRAWDOWN
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JOB NO. 4901107	DWG. NO. / REV. NO. CHART2 / 1	CLIENT LANTNAVFACENGCOM
		FIGURE 4-3



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DATE 5-23-91	SCALE SHOWN	TITLE Relationship Between Observed Groundwater Drawdown & Mean Tide Height versus Barometric Efficiency	
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JOB NO. 4901107	DWG. NO. / REV. NO. CHART1 / -	CLIENT NAVFAC LANTDIV Q AREA	FIGURE 4-4

SW-2

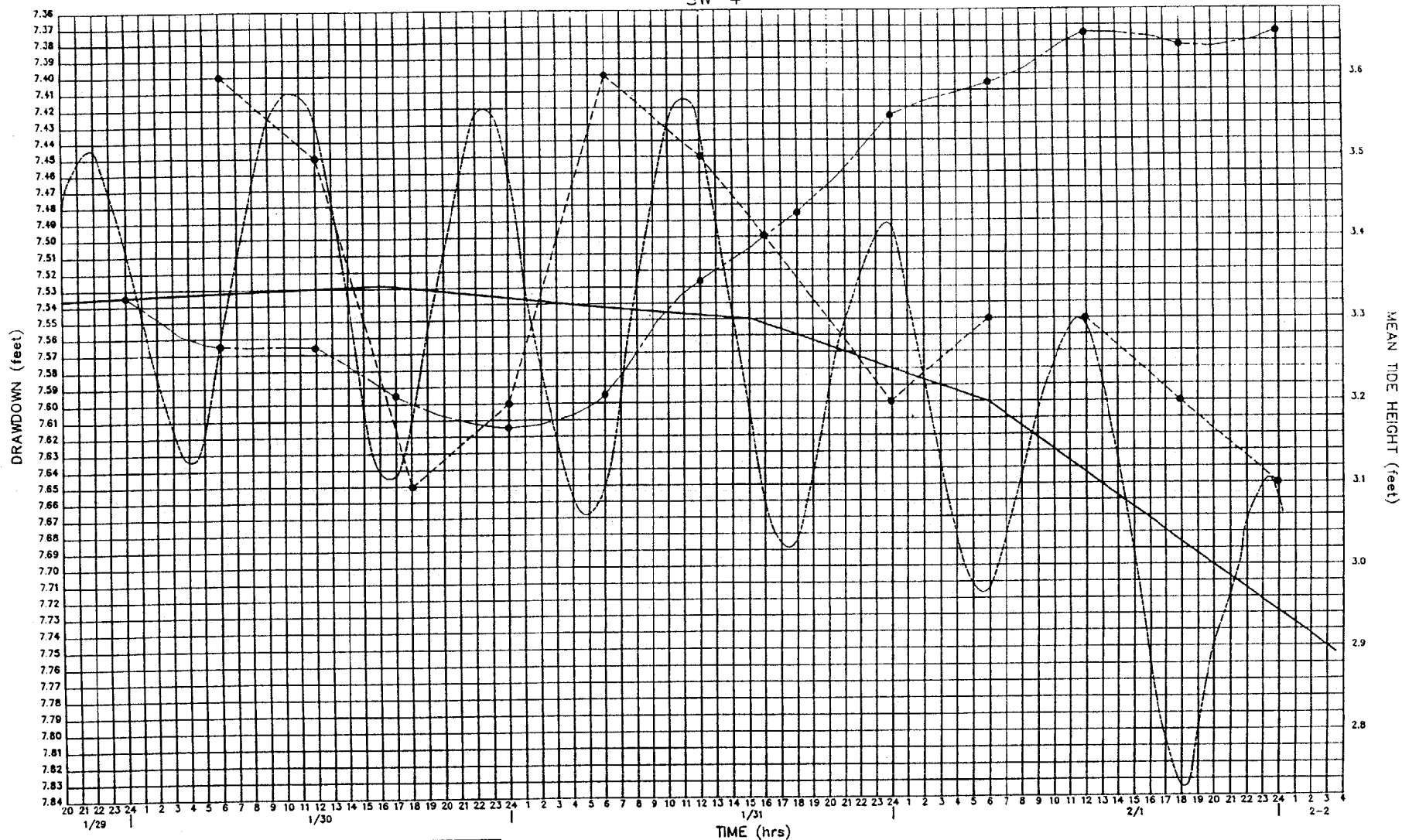


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JOB NO. 4901107	DWG. NO. / REV. NO. CHART2 / -	CLIENT NAVFAC LANTDIV Q ARE	SURE 4-5



SW-4



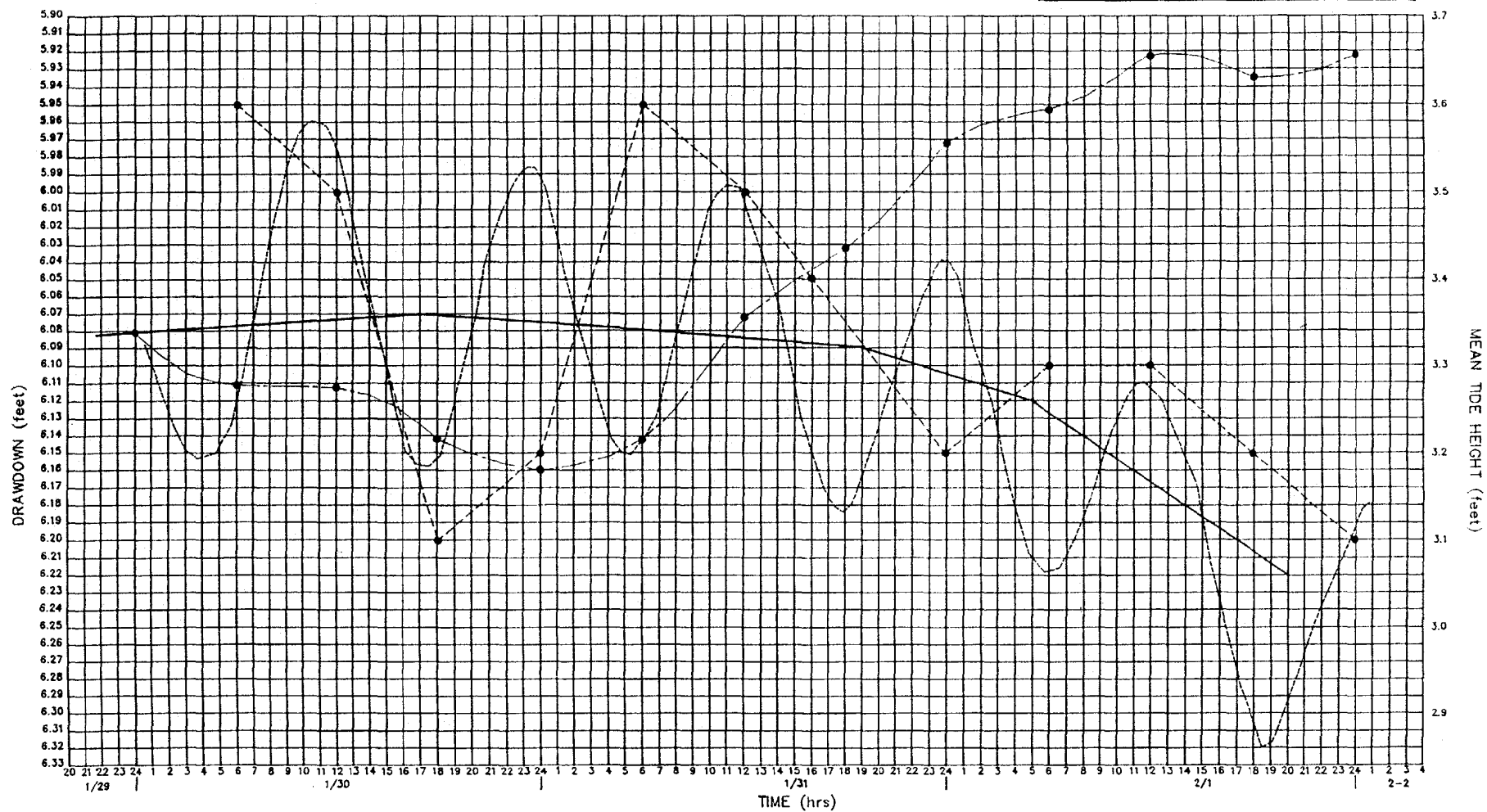
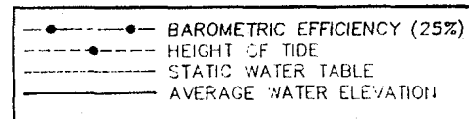
- - - • - - - BAROMETRIC EFFICIENCY (25%)  
 - - - • - - - HEIGHT OF TIDE  
 - - - - - STATIC WATER TABLE  
 - - - - - AVERAGE WATER ELEVATION



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JOB NO. 4901107	DWG. NO./ REV. NO. CHART 4 / -	CLIENT NAVFAC LANTDIV Q AREA
		FIGURE 4-6

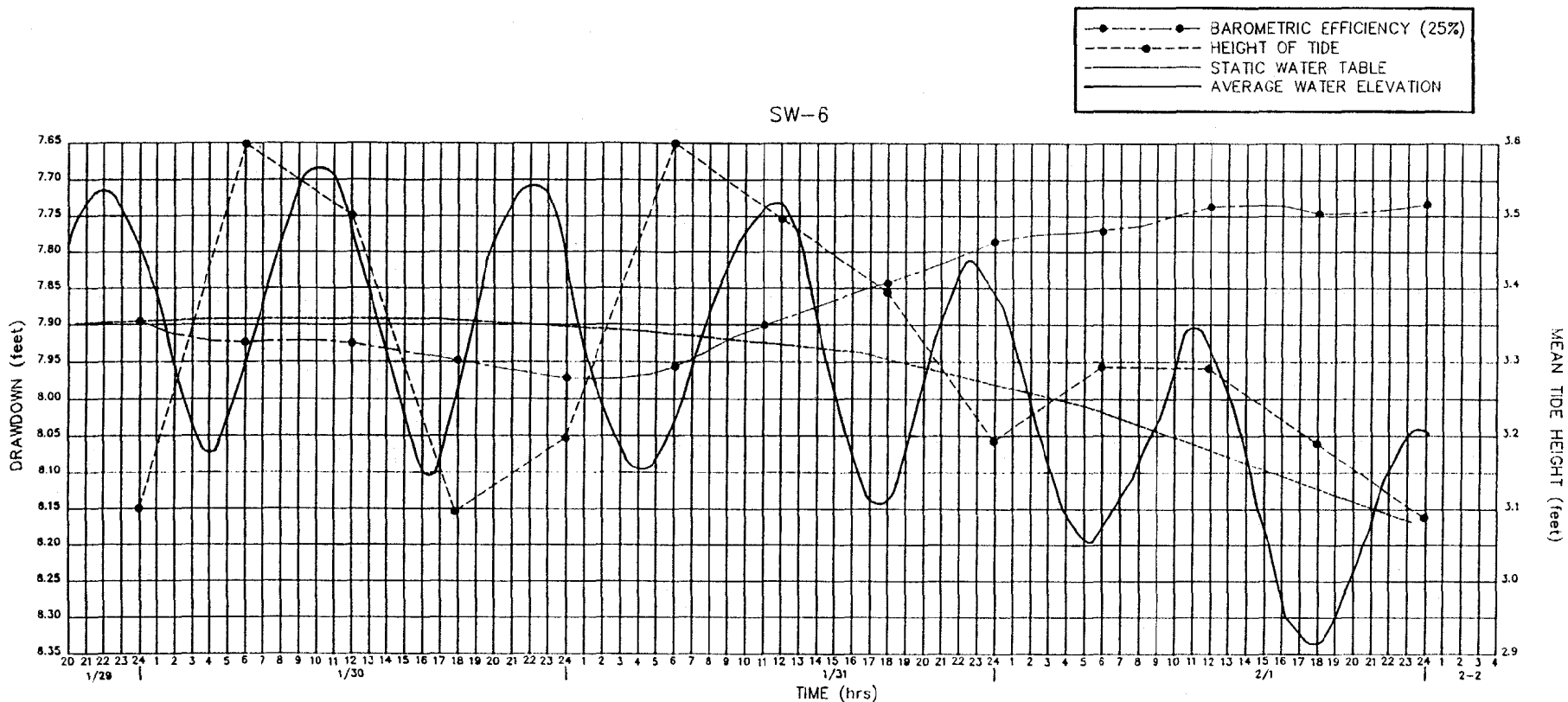
SW-5



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DATE 5-23-91	SCALE SHOWN	TITLE Relationship Between Observed Groundwater Drawdown & Mean Tide Height versus Barometric Efficiency
DRAWN BY RG/LAF	APPROVED BY	
JOB NO. 4901107	DWG. NO. / REV. NO. CHART5 / -	CLIENT NAVFAC LANTDIV Q AREA

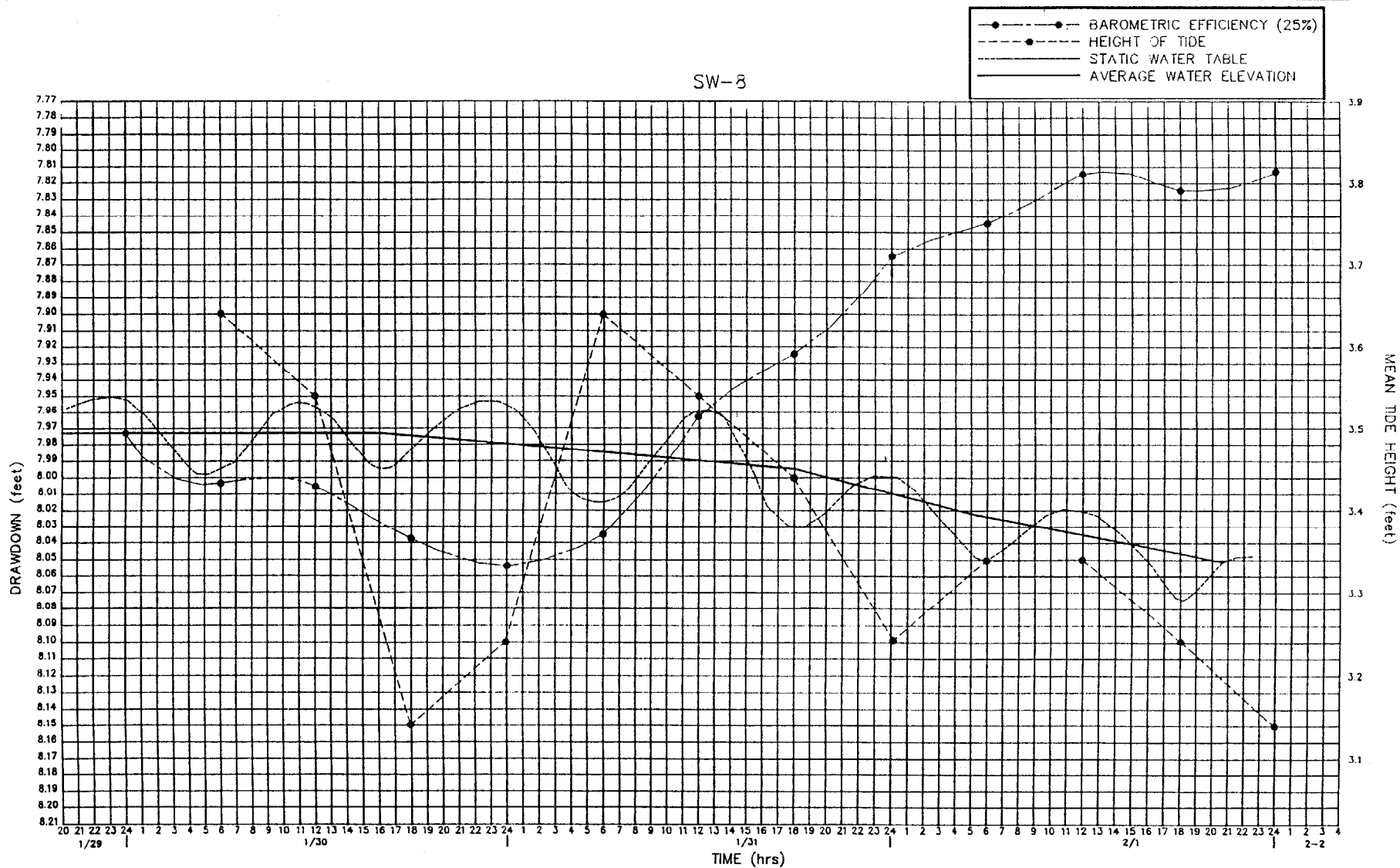
FIGURE 4-7



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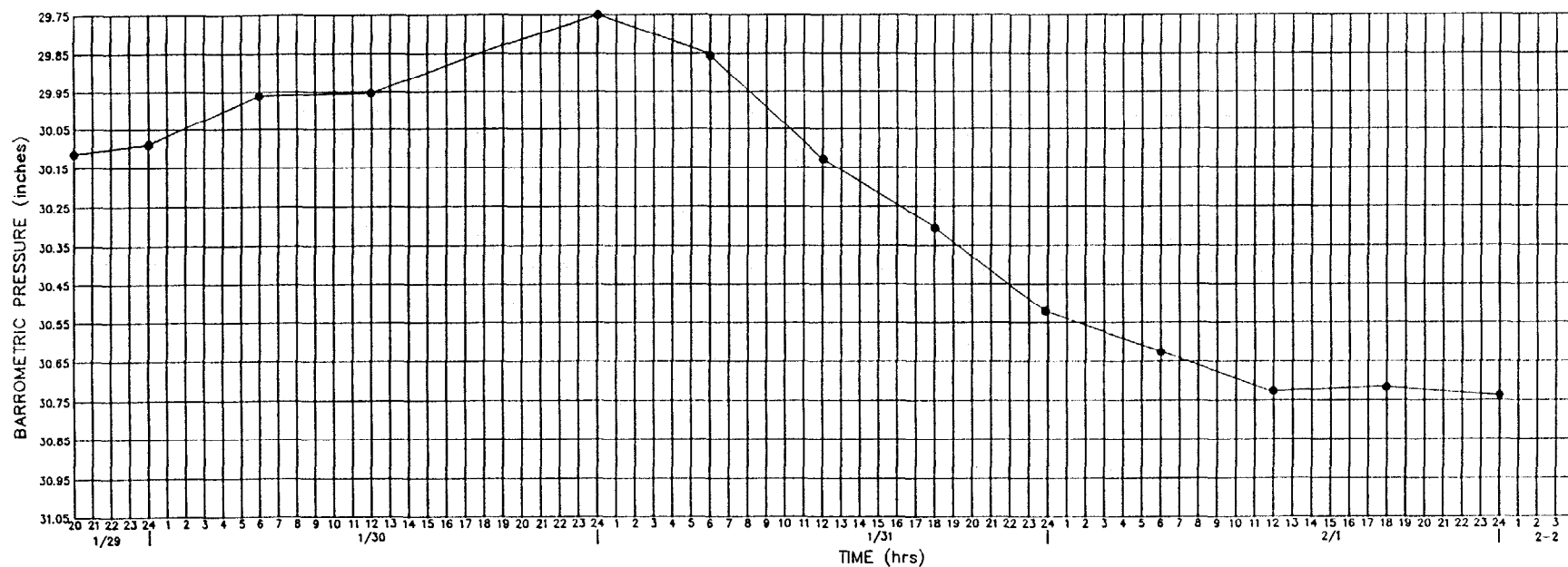
DATE 5-23-91	SCALE SHOWN	TITLE Relationship Between Observed Groundwater Drawdown & Mean Tide Height versus Barometric Efficiency	
DRAWN BY RC/LAF	APPROVED BY		
JOB NO. 4901107	DWG. NO. / REV. NO. CHART / -	CLIENT NAVFAC LANTDIV Q AREA	FIGURE 4-8

SW-8



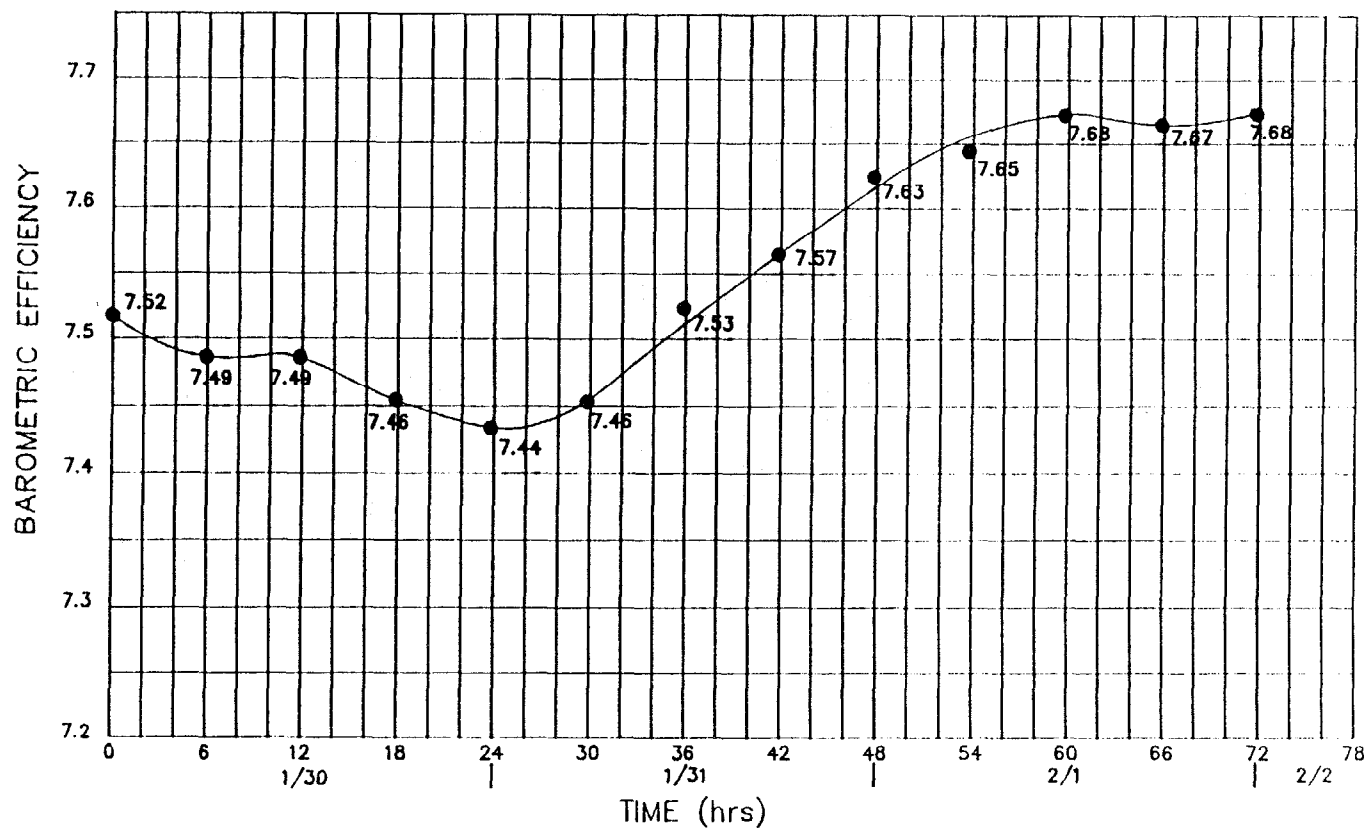
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DATE 5-23-91	SCALE SHOWN	TITLE Relationship Between Observed Groundwater Drawdown & Mean Tide Height versus Barometric Efficiency	
DRAWN BY RG/LAF	APPROVED BY		
JOB NO. 4901107	DWG. NO. / REV. NO. CHART3 / -	CLIENT NAVFAC LANTDIV Q AREA	P 4-9



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DATE 5-23-91	SCALE SHOWN	TITLE ACTUAL BAROMETRIC PRESSURE GRAPH FOR DURATION OF PUMP TEST (INCHES OF HG)	
DRAWN BY RG/LAF	APPROVED BY		
JOB NO. 4901107	DWG. NO. / REV. NO. CHART9 / -	CLIENT NAVFAC LANTDIV Q AREA	FIGURE 4-10



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SHOWN

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CHART8 / -

TITLE

GRAPH OF BAROMETRIC PRESSURE TIMES  
0.25 (25%) BAROMETRIC EFFICIENCY

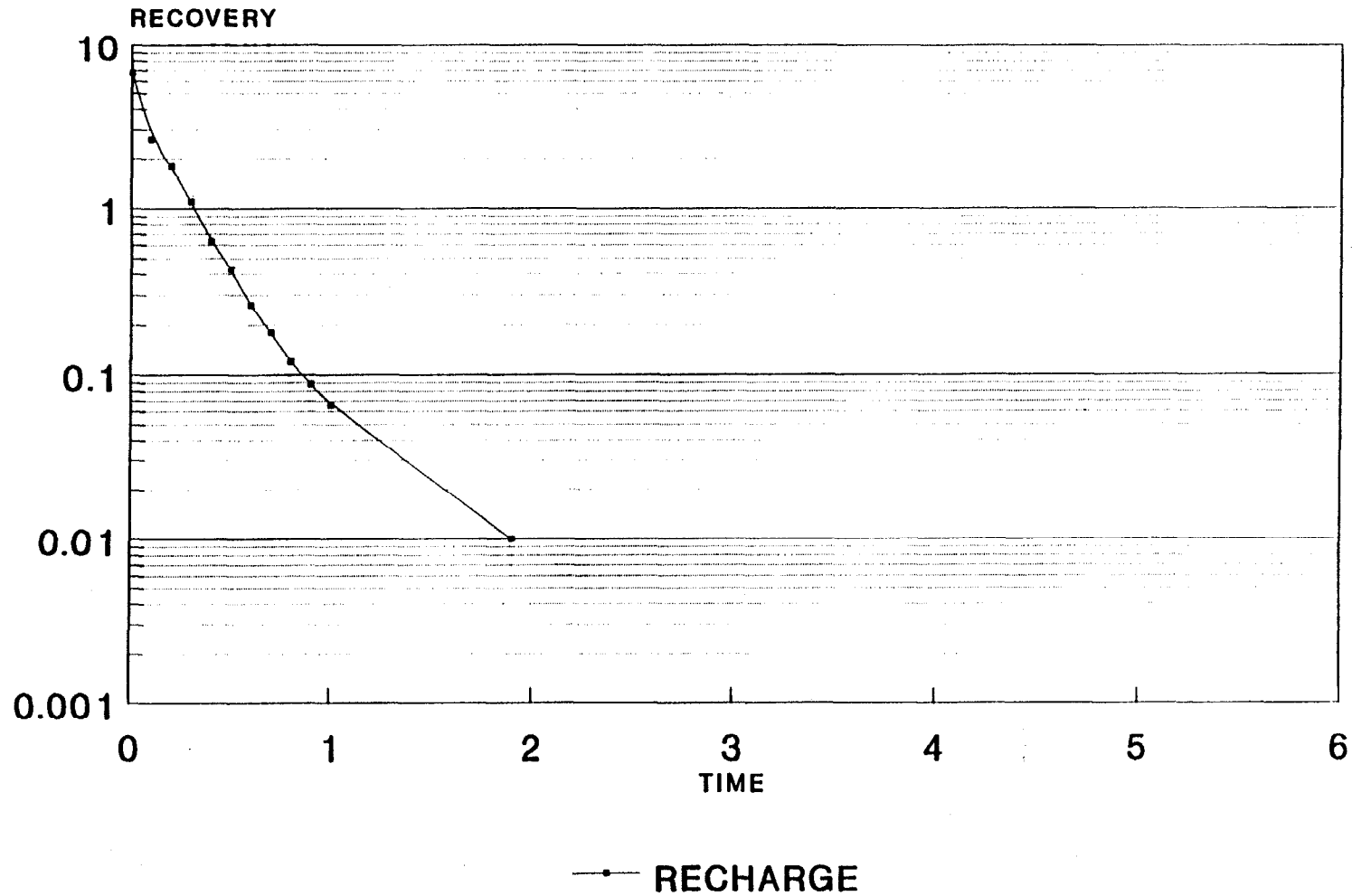
CLIENT

NAVFAC LANTDIV Q AREA

FIGURE

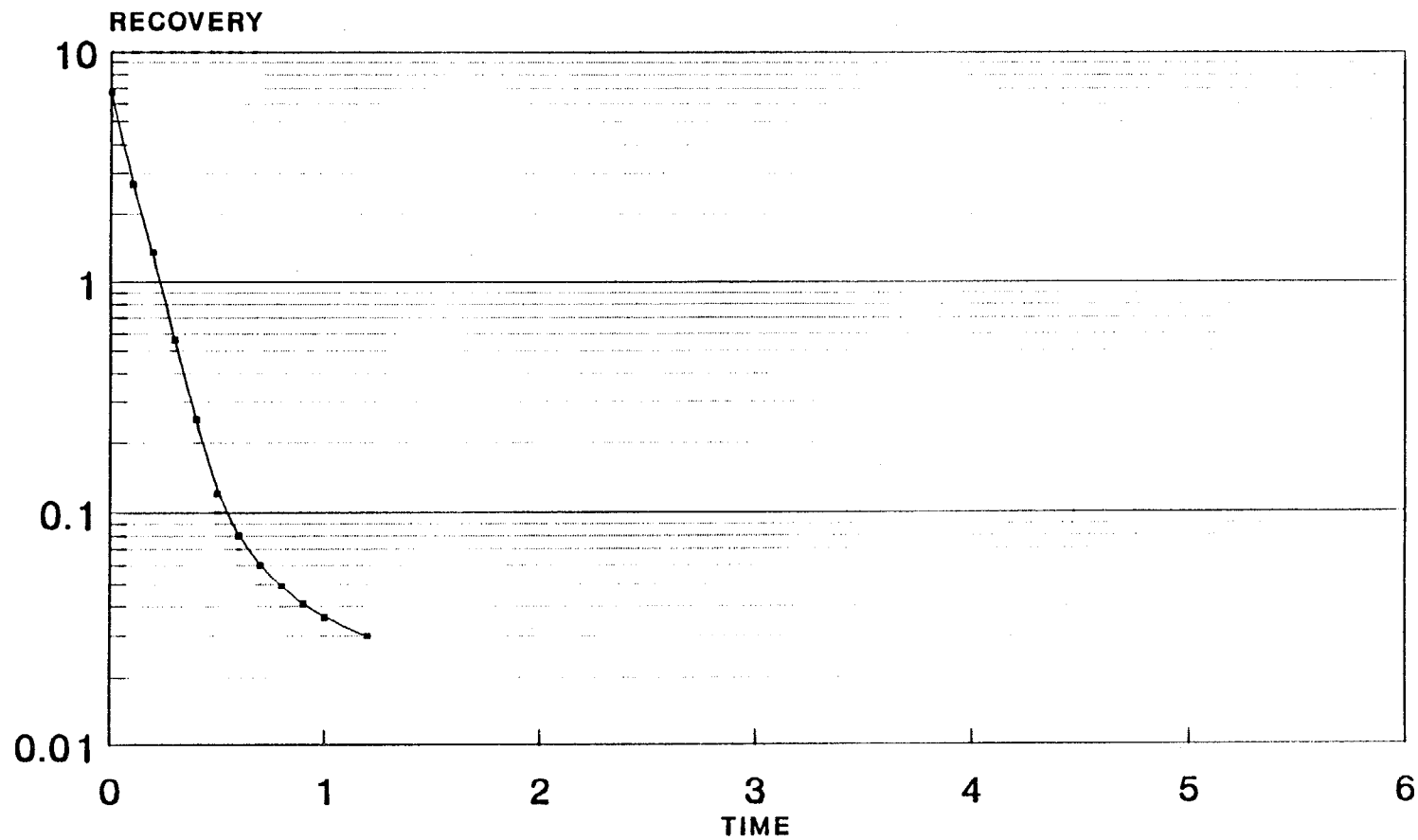
4-11

# SW-6



TIME(min.) vs. DRAWDOWN(ft.)

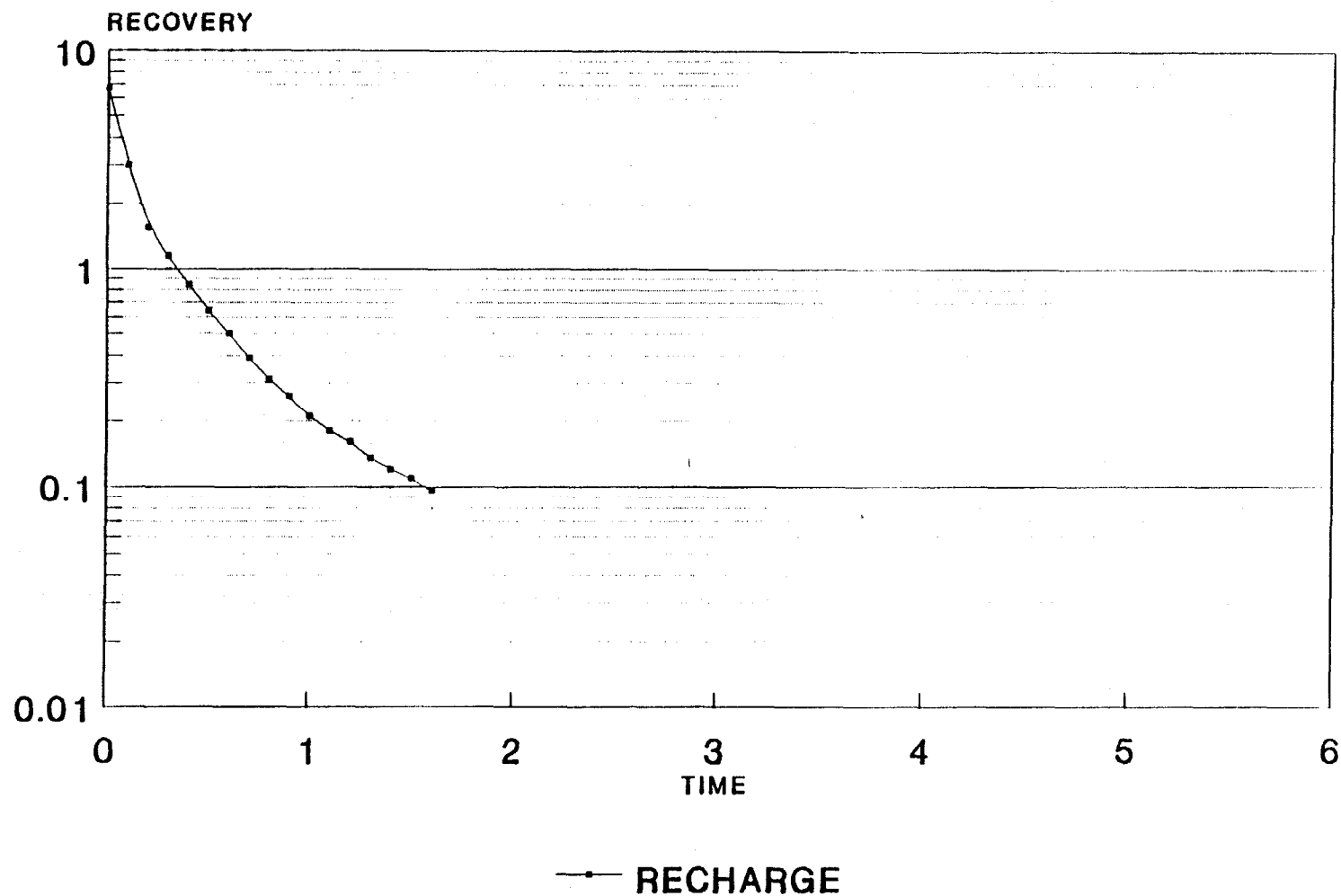
# SW-7



TIME(MIN.) VS. DRAWDOWN(FT.)

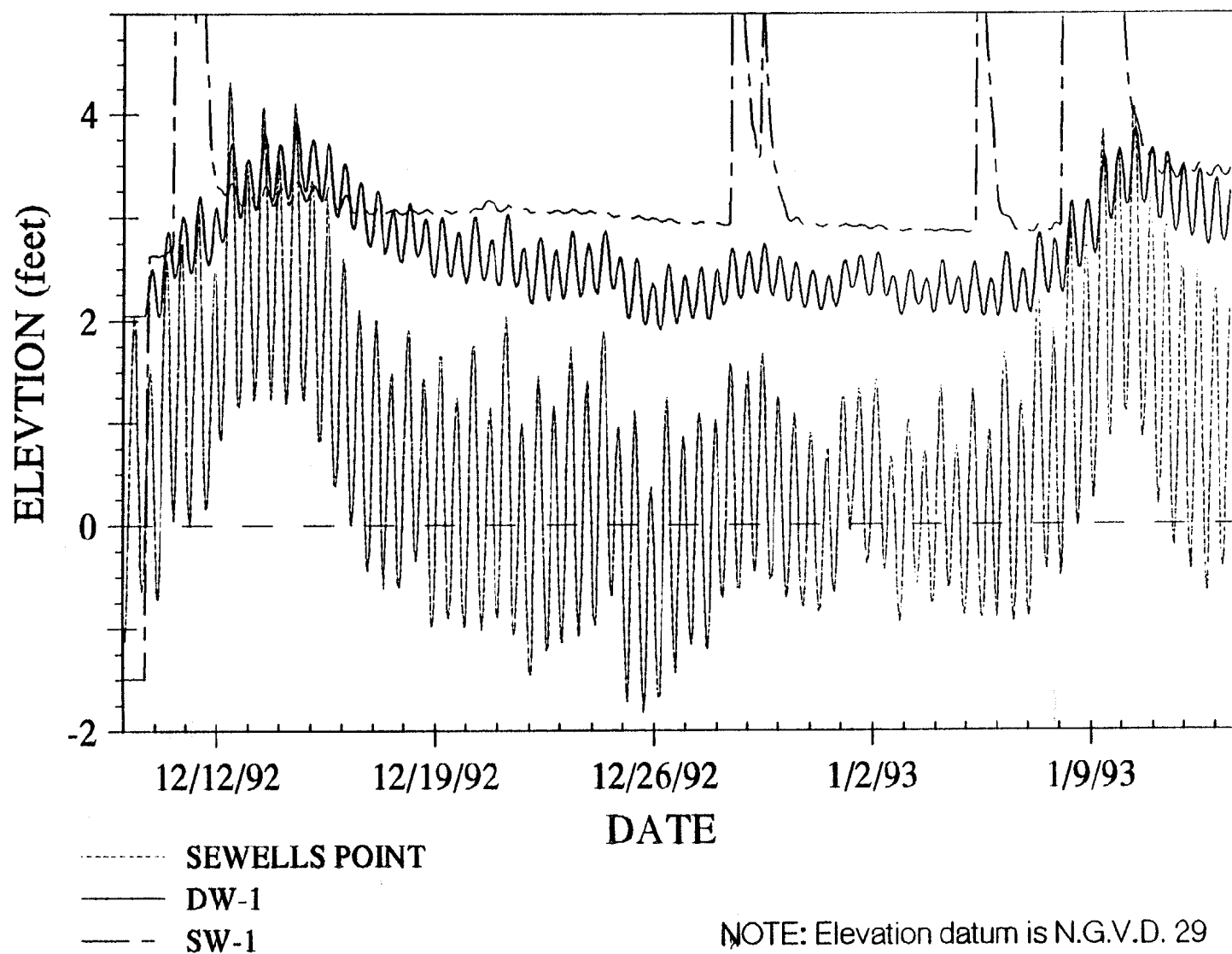


SW-8

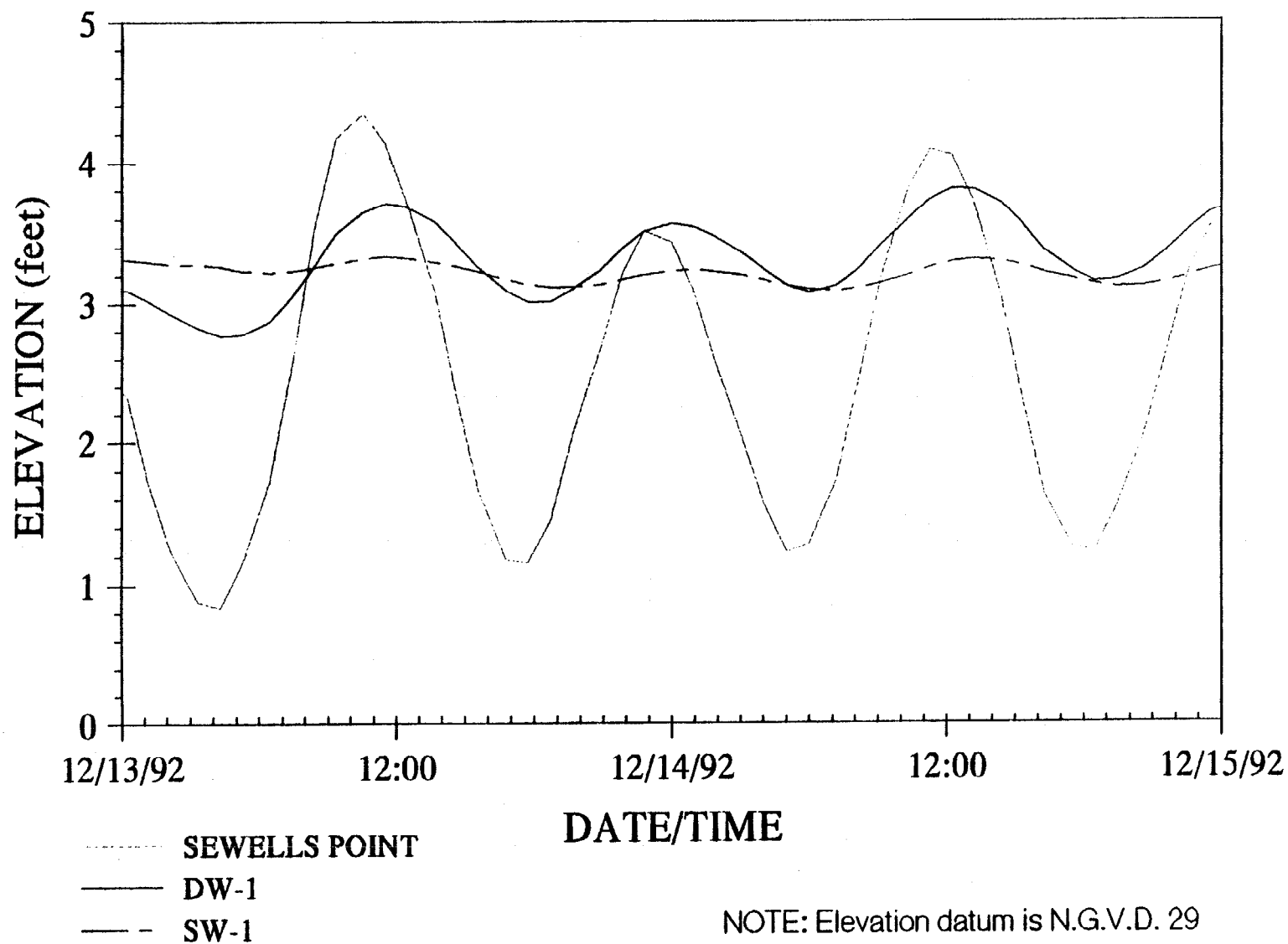


TIME(MIN.) VS. DRAWDOWN(FT.)

**Figure 4-15**  
**Sewells Point Tide, DW-1 and SW-1 Groundwater Elevations**



**Figure 4-16**  
**Sewells Point Tide, DW-1 and SW-1 Groundwater Elevations (Detail)**



**Figure 4-17**  
**Elizabeth River and Local Piezometer Water Level Record**

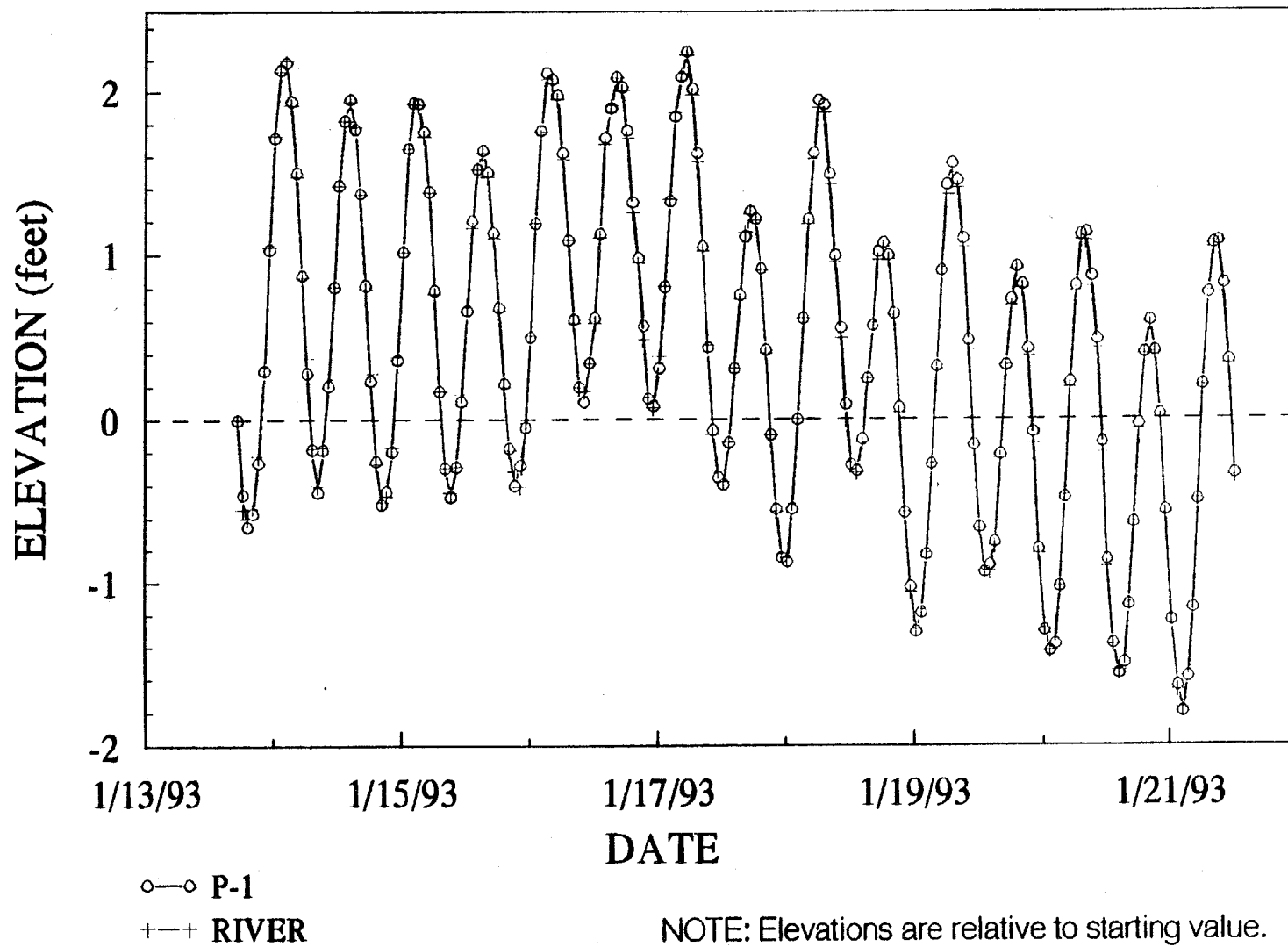
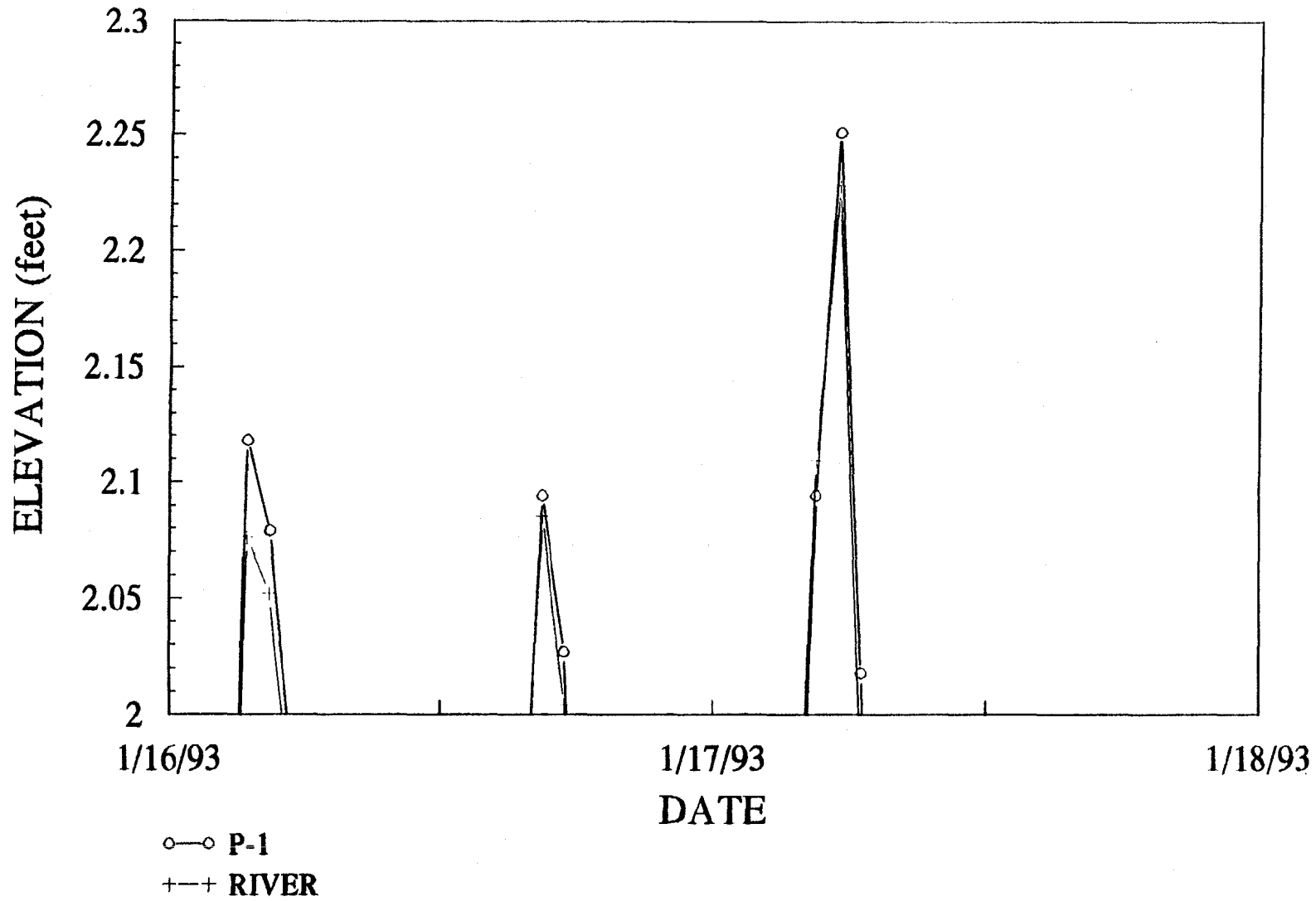
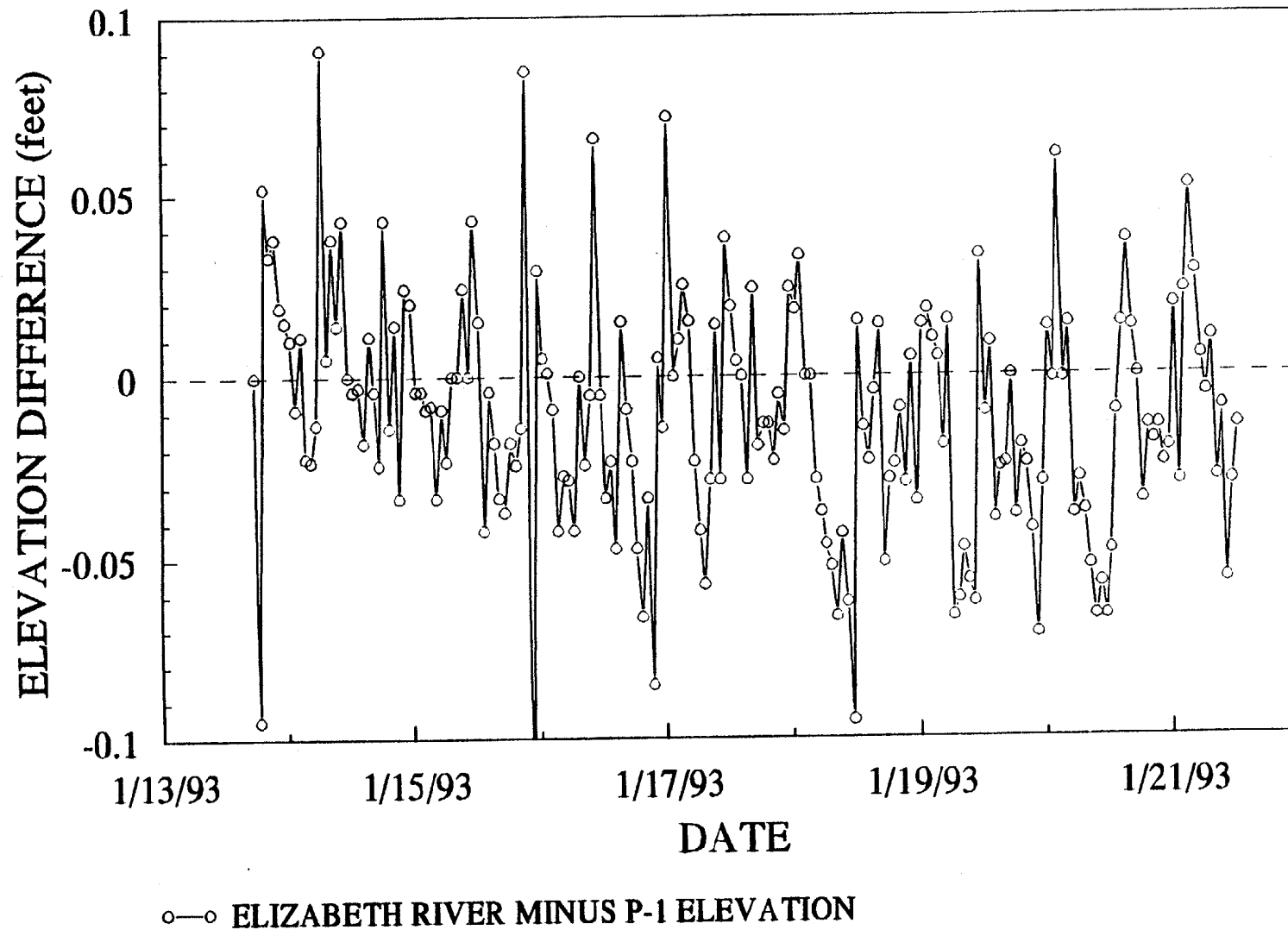


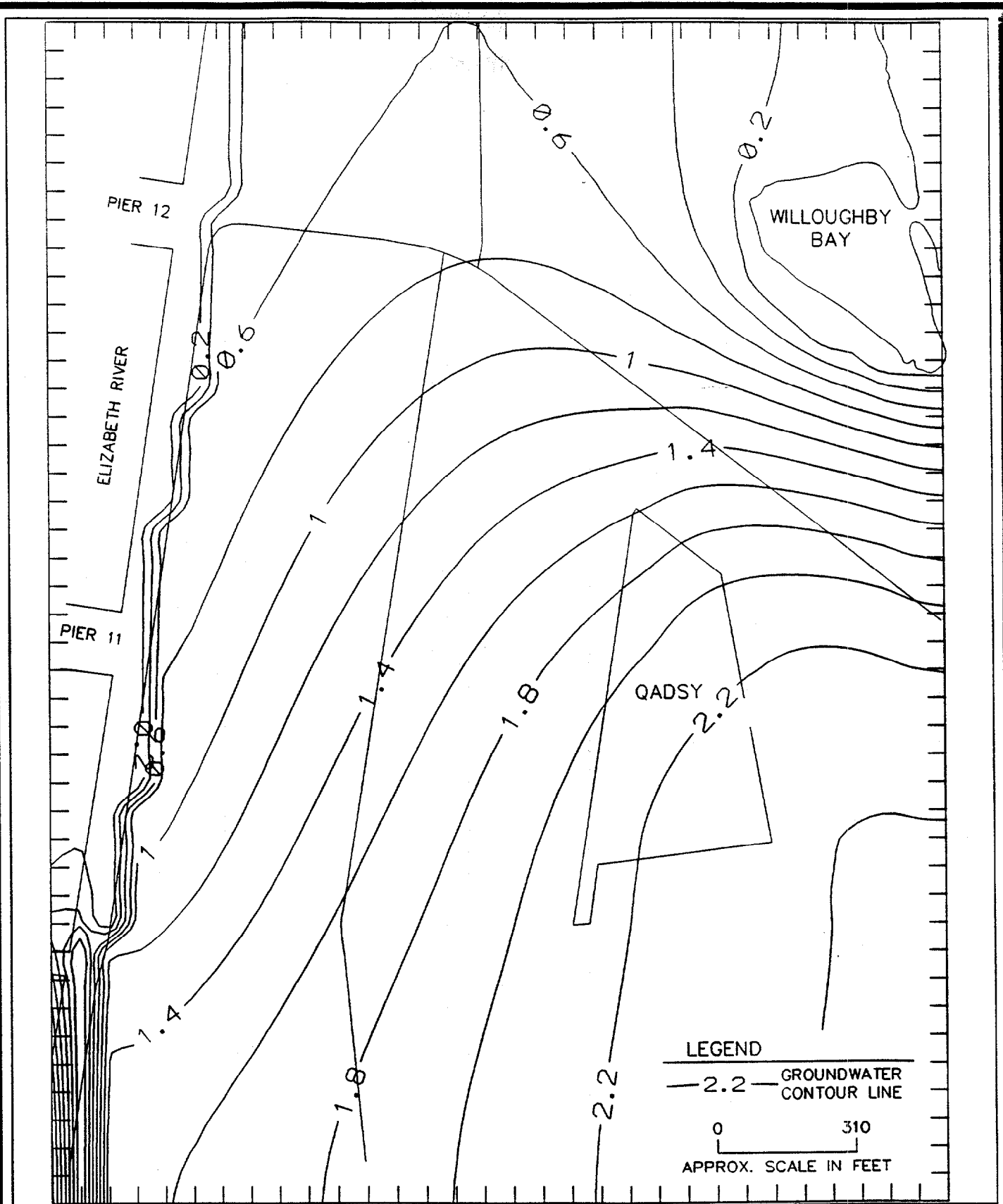
Figure 4-18  
Elizabeth River Elevation and Local Piezometer (Detail)



NOTE: Elevations are relative to starting value.

**Figure 4-19**  
**Elizabeth River Elevation and Local Piezometer Difference**





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TITLE

SIMULATED HEADS SHALLOW AQUIFER  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT

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FIGURE

4-20

Time in days  
14600.0

X Min= 0  
X Max= 2000  
Y Min= 0  
Y Max= 2687  
Z Min= 0  
Z Max= -110

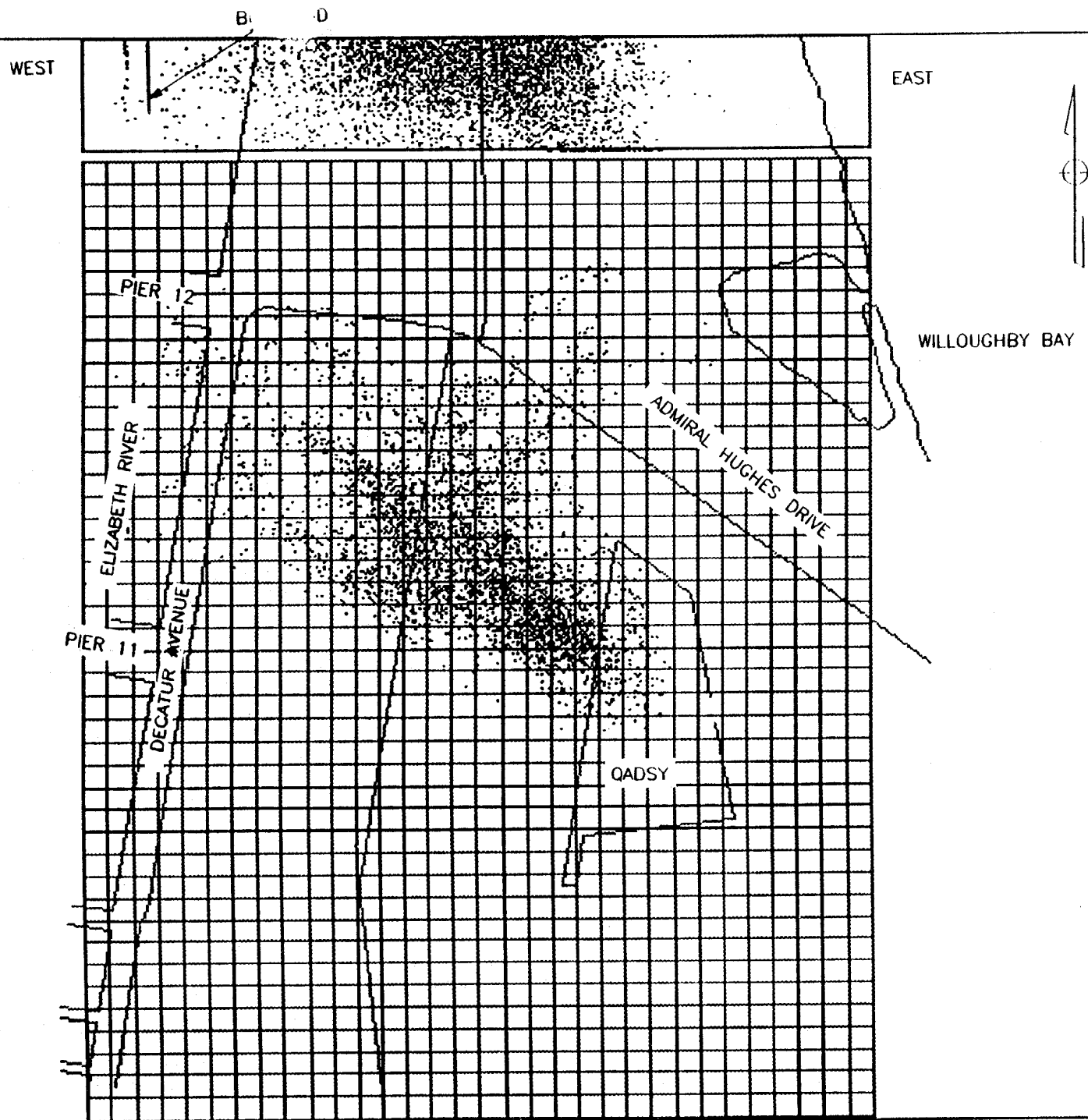


Figure 4-21

INTERTRANS Model - Simulation with 100 Particles



Time in days  
14600.0

X Min= 0  
X Max= 2000  
Y Min= 0  
Y Max= 2687  
Z Min= 0  
Z Max= -110

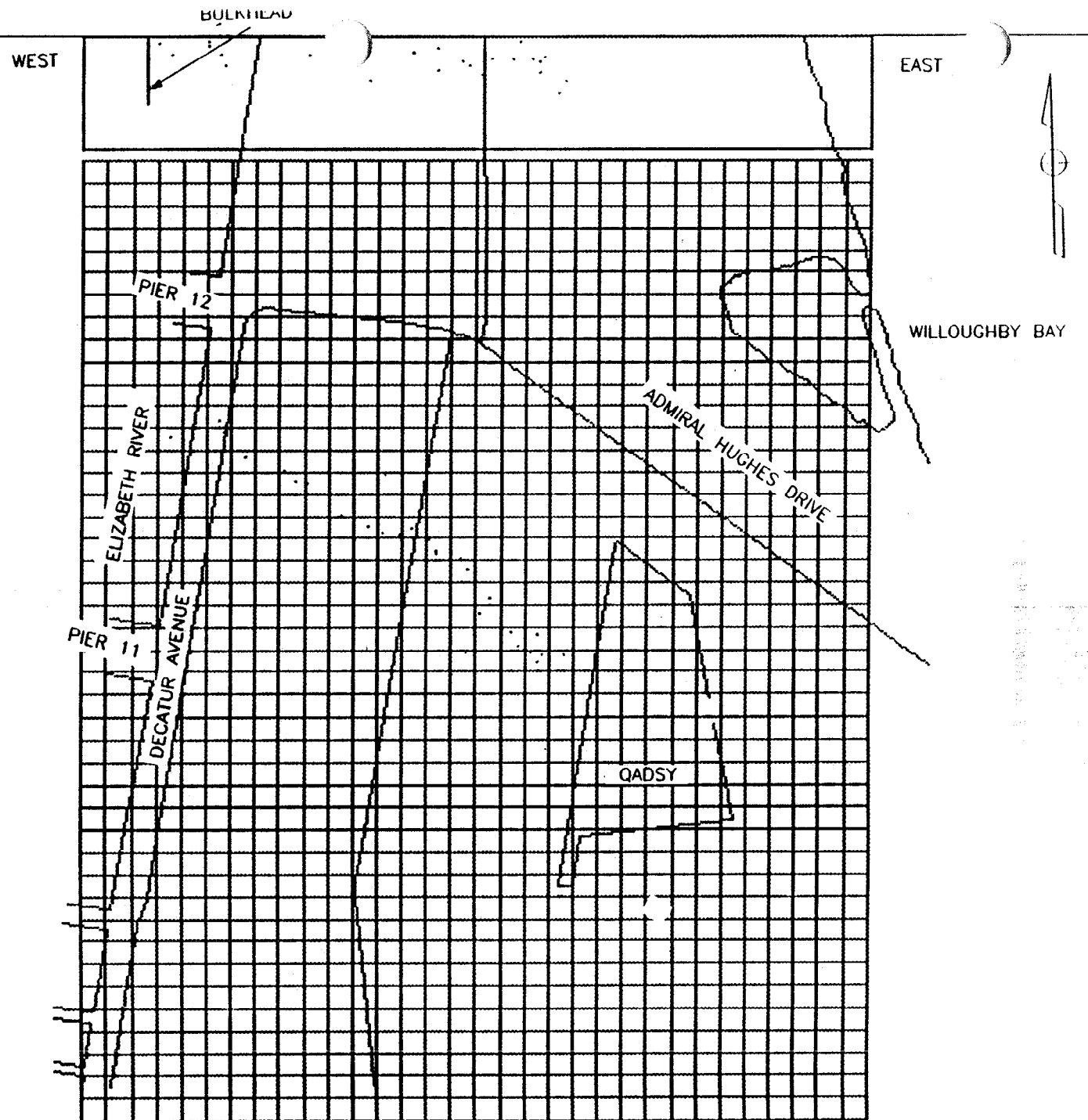
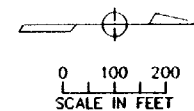
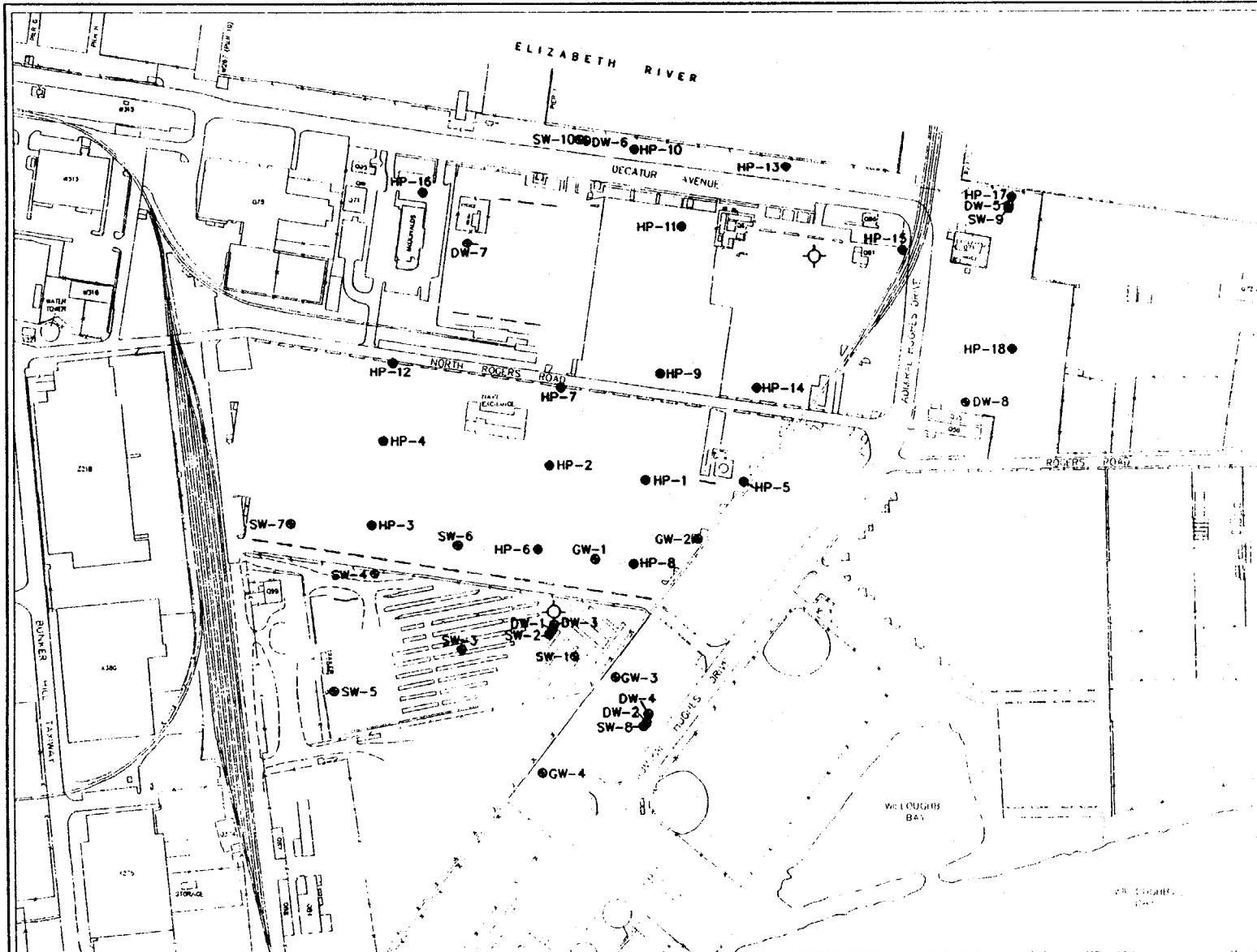


Figure 4-22

INTERTRANS Model - Simulation with 1 Particle



#### LEGEND

- HYDROPUNCH LOCATION
- MONITOR WELL LOCATION
- SURFACE WATER LOCATION
- ⊙ AIR SPARGING / SOIL VAPOR EXTRACTION PILOT STUDY LOCATION



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DWG. NO./ REV. NO  
PILOT150

TITLE

MONITOR WELL, HYDROPUNCH, AND  
AS/SVE PILOT STUDY LOCATIONS  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT

NAVFAC - Q AREA

FIGURE

4-23

## 5.0 NATURE AND EXTENT OF CONTAMINATION

This section of the report presents the results of the site characterization (sampling and analytical program) for each of the media sampled. The analytical results for each media are compared with the data from background samples to more accurately depict fluctuations in contaminant levels in those media under scrutiny.

### 5.1 Soils

For the purposes of the investigation, the site was broken down into five distinct parcels based on the historical use of each area (Sections 3.1 and 3.2). However, the analytical parameters for each parcel were essentially the same. The areas investigated include: the HM area, PPA, TA, and EY (see Section 2.1). The soil sample locations and areas investigated are shown on Figure 5-1.

During this discussion, individual samples will be referred to by a three- or four-digit code. The first two letters refer to the sample area (TA for Transit Area, etc.), the next number refers to the areal location of the sample, and the final number (1 or 2) refers to the depth that the sample was taken from the surface ("1" denotes 0 to 18 inches, "2" denotes 18 to 36 inches). The final digit is omitted when a single sample was taken from 0 to 36 inches. Soil samples were also taken from most monitor well locations during installation. These are referred to by the prefix SW. The interval for SW samples was 0 to 10 feet.

Background soil samples were collected from DW-2 and SW-8 and analyzed for VOCs, TPH, TCLP metals, and percent moisture.

#### 5.1.1 Transit Area (TA)

##### 5.1.1.1 VOCs

Three VOCs were detected in the soil samples from the TA. Acetone was detected in each of the borings ranging in concentration from undetected in the field duplicate sample of TA-1-2, to 650  $\mu\text{g/kg}$  in sample TA-1-1. The samples from TA-3-1, TA-3-2, TA-5-1, and TA-5-2 contained 59, 370, 540, and 440  $\mu\text{g/kg}$ , respectively. The soil samples are below the Region III risk-based concentrations (RBC) for commercial/industrial soils of Superfund sites (100,000  $\mu\text{g/kg}$ ).

Total xylenes (21  $\mu\text{g/kg}$ ) and PCE (estimated 2  $\mu\text{g/kg}$ ) were detected in sample TA-1-1, but not in any other TA samples, and are below RBCs (100,000 and 55,000  $\mu\text{g/kg}$ , respectively). Methylene chloride was detected at low levels (less than 15  $\mu\text{g/kg}$ ) in all but one sample (TA-

3-2). However, because methylene chloride was also found in low levels in the blank sample and the background samples, it is unlikely that it exists as a soil contaminant. No VOCs other than methylene chloride were found in the background samples. The analytical data are summarized in Appendix G, Table G-1.

#### 5.1.1.2 SVOCs

12 SVOCs were detected in the samples from the TA.

- Benzo(a)anthracene was estimated in sample SS-20 at 82 µg/kg.
- Benzo(a)pyrene was estimated in sample SS-20 at 85 µg/kg and is below the RBC for industrial soil (390 µg/kg).
- Benzo(b)fluoranthene was estimated in sample SS-20 at 130 µg/kg and is below the RBC for industrial soil (3900 µg/kg).
- Benzo(g,h,i)perylene was estimated in sample SS-20 at 78 µg/kg.
- Bis(2-ethylhexyl)phthalate was estimated at 820 µg/kg in sample TA-1-1 and detected at 980 µg/kg in TA-1-2 field duplicate (FD). An estimated concentration of 47 and 100 µg/kg was detected in samples SS-19 and SS-20, respectively, and 140 and 110 µg/kg was detected in the field duplicate samples of TA-1-2 and in TA-5-2, respectively.
- Estimated concentrations of chrysene was detected in SS-20 at 110 µg/kg and is below the RBC for industrial soil (390,000 µg/kg).
- Estimated di-n-butylphthalate concentrations of 900 µg/kg and 53 µg/kg were detected in samples TA-1-2 and its field duplicate.
- 1,4-dichlorobenzene was estimated in field duplicate sample TA-1-2 and TA-5-2 at 140 and 110 µg/kg and is below the RBC for industrial soil (120,000 µg/kg).
- Fluoranthene was estimated in sample SS-20 at 170 µg/kg and is below the RBC for industrial soil (41,000,000 µg/kg).
- Indeno(1,2,3-cd)pyrene was estimated in sample SS-20 at 170 µg/kg and is below the RBC for industrial soil (3900 µg/kg).
- Phenanthrene was estimated in sample SS-20 at 92 µg/kg.

- Pyrene was estimated in sample SS-20 at 140 µg/kg and is below the RBC for industrial soil (31,000.000 µg/kg).

No SVOCs were detected in the background samples. The analytical data are summarized in Appendix G, Table G-2.

#### 5.1.1.3 TPH

TPH was detected in samples TA-1-1, TA-1-2 (and TA-1-2 FD), TA-5-1, TA-5-2, SS-9, and SS-12 at concentrations ranging from 39.4 to 4400 ppm. The TA-1 samples contained hydrocarbons that closely matched the lube oil standard, and the TA-5 samples contained hydrocarbons that did not match any of the reference standards. No evidence of TPH contamination was found in the samples from TA-3-1 and TA-3-2. The samples from TA-1-1, TA-1-2 FD, TA-5-1, and SS-9 exceeded the 100 ppm VDEQ action level for disposal in a sanitary landfill.

In interpreting the results, ESE evaluated the difference between the TPH concentration in upper and lower sample intervals at each location. Characteristically, a significant drop in concentration was noted from the upper to the lower sample, due to the gradual infiltration of contaminants through the vadose zone by percolation. This relationship was established in the samples from TA-1 and TA-5.

Where the lower sample (18 to 36 inches) was noted to be above the 100 ppm cleanup guideline, further sampling was conducted to more accurately delineate the vertical extent of any pockets of soil that may require remediation. The analytical data are summarized in Appendix G, Table G-3.

Two soil samples from one soil boring were collected on 14 and 15 December 1992 pursuant to the revised RI/FS work plan. The samples were taken around the known areas of TPH contamination at the 3- to 5-foot and 5- to 7-foot depth intervals (Figure 5-1). The samples were taken at different depths to determine the vertical extent of TPH contamination.

Both soil samples were found below the detection limits for TPH at the TA area. Equipment and field blanks taken were all below detection levels for TPH. The results are summarized in Appendix G, Table G-6.

#### 5.1.1.4 TCLP Organics

TCLP VOC, SVOC, pesticide, and herbicide organics were not detected in any of the samples from the TA. The analytical data are summarized in Appendix G, Table G-4.

#### 5.1.1.5 TCLP Metals

- Arsenic (120 to 270 µg/kg) was detected in the extracts from all soil samples collected from the TA and was below the TCLP standard (5,000 µg/kg). This range of concentrations was higher than that observed in the background samples (105 to 120 µg/kg).
- Barium (155 to 425 µg/kg) was detected in the extracts from all soil TA samples and was below the TCLP standard (100,000 µg/kg). This range of values was lower than those observed in the background samples (357 to 568 µg/kg).
- Cadmium was detected in the samples from TA-1-2, TA-1-2 FD, TA-4, TA-5-1, and TA-5-2 with a range of values from 3 to 6 µg/kg, below the TCLP standard (1000 µg/kg). The two background samples had values of 4 µg/kg.
- Chromium (7 to 17 µg/kg) was detected in all the samples and was below the TCLP standard (5,000 µg/kg). It was also detected in both background samples at concentrations of 12 and 14 µg/kg.
- Lead (47 to 68 µg/kg) was detected in the samples from TA-1-2, TA-2, TA-3-1, TA-3-2, and TA-5-2 and was below the TCLP standard (5,000 µg/kg). Lead was detected in the deeper background sample only, at a concentration of 59 µg/kg.
- Selenium (59 to 116 µg/kg) was detected in all but three TA samples and was below the TCLP standard (1,000 µg/kg). It was not detected in the background samples.
- Silver (7 to 9 µg/kg) was detected in the samples from TA-1-2 FD, TA-3-1, and TA-4 and was below the TCLP standard (5,000 µg/kg). It was detected in the deeper background sample at a concentration of 11 µg/kg.

The results for all the TCLP metals were well below the applicable TCLP standard for each. In many cases, although the instrument was sensitive enough to detect an analyte, its concentration was below the required detection limit for the analysis. The analytical data are summarized in Appendix G, Table G-5.

#### 5.1.1.6 IOCs

A total of nine IOCs were detected in the samples collected from the TA.

- Aluminum was detected in samples SS-19 and SS-20 at 4060 and 4650 mg/kg, respectively, and below the RBC (1,000,000 mg/kg) for industrial soil.

- Arsenic was estimated in samples SS-19 and SS-20 at 9 and 13.2 mg/kg, respectively and below the RBC (310 mg/kg) for industrial soil. Arsenic was above the RBCs for Arsenic as a carcinogen (1.6 mg/kg).
- Barium was detected in samples SS-19 and SS-20 at 34.2 and 56.6 mg/kg, respectively, and below the RBC (72,000 mg/kg) for industrial soil.
- Chromium was detected in samples SS-19 and SS-20 at 17.2 and 19.9 mg/kg, respectively, and below the RBC (5100 mg/kg) for industrial soil.
- Copper was detected in samples SS-19 and SS-20 at 12.3 and 21 mg/kg, respectively and below the RBC (38,000 mg/kg) for industrial soil.
- Lead was estimated in sample SS-19 at 17 mg/kg. Lead was detected in sample SS-20 at 50.6 mg/kg.
- Manganese was estimated in samples SS-19 and SS-20 at 251 and 287 mg/kg, respectively, and below the RBC (5100 mg/kg) for industrial soil.
- Nickel was detected in samples SS-19 and SS-20 at 14.8 and 11.8 mg/kg, respectively, and below the RBC (20,000 mg/kg) for industrial soil.
- Vanadium detected in samples SS-19 and SS-20 at 35.8 and 53.2 mg/kg, respectively, and below the RBC (7200 mg/kg) for industrial soil.

#### 5.1.1.7 Pesticides/PCBs

A total of three pesticides were detected in the samples collected from the TA.

- Alpha-chlordane was detected in samples SS-19 and SS-20 at 0.0077 and 0.012 mg/kg, respectively.
- DDE was estimated in sample SS-20 at 0.0018 mg/kg and below the RBC (8.4 mg/kg) for industrial soil.
- Gamma-chlordane was detected in samples SS-19 and SS-20 at 0.01 and 0.014 mg/kg, respectively.

### 5.1.2 **Truck and Equipment Storage Yard (EY)**

#### 5.1.2.1 VOCs

A total of four VOCs were detected in the samples from the EY area.

- Acetone was detected in the samples from EY-4-2 and EY-7-2 at concentrations of 11 and 7 (estimated)  $\mu\text{g/kg}$ , respectively, below the RBC (100,000  $\mu\text{g/kg}$ ).
- Benzene was detected in the sample from EY-3-2 at an estimated concentration of 2  $\mu\text{g/kg}$ , below the RBC (99,000  $\mu\text{g/kg}$ ).
- PCE was detected in the sample from EY-2-1 at a concentration of 11  $\mu\text{g/kg}$ , below the RBC (55,000  $\mu\text{g/kg}$ ).
- Methylene chloride was detected in all the soil samples from the EY area, as well as in a blank sample. The concentrations were all noted to be below 25  $\mu\text{g/kg}$ ; therefore, its presence as a soil contaminant cannot be confirmed.

No VOCs, other than methylene chloride, were detected in the background samples. The analytical data are summarized in Appendix G, Table G-1.

#### 5.1.2.2 TPH

Only one sample was found to contain a detectable TPH quantity close to one of the reference standards used by the laboratory. Fuel oil #6 was detected at 50 ppm in the sample from EY-5-1.

An unquantifiable amount of TPH that did not match any reference standards (possibly representing a degradation product) was detected in the sample from EY-7-2. The level of contamination noted in EY-5-1 is below the 100 ppm VDEQ action level. The analytical data are summarized in Appendix G, Table G-3.

#### 5.1.2.3 TCLP VOCs

TCLP VOC, SVOC, pesticide, and herbicide organics were not detected in any of the samples from the EY area. The analytical data are summarized in Appendix G, Table G-4.

#### 5.1.2.4 TCLP Metals

Barium was detected in all the EY samples at concentrations ranging from 154 to 452  $\mu\text{g/kg}$  with a mean value of 247  $\mu\text{g/kg}$ . The range of results was comparable to those seen in the background samples and concentrations fall well below the TCLP standards (100,000  $\mu\text{g/kg}$ ).

Arsenic, chromium, lead, mercury, and selenium were also detected in various EY samples. Although the instrument was sensitive enough to detect the analytes of concern, the concentrations were below required detection limits for the analysis. The analytical data are summarized in Appendix G, Table G-5.



### 5.1.3 Petroleum Products Area (PPA)

#### 5.1.3.1 VOCs

A total of five VOCs were detected in specific soil samples from the PPA. These included methylene chloride, acetone, 1,2-DCE, PCE, and toluene. Methylene chloride was found in most of the samples ranging in concentration from an estimated 4 to 39 µg/kg. Analytical results of the blank samples from certain of the sample sets also identified methylene chloride. Because methylene chloride is a common laboratory contaminant and was also found in blank samples, its presence as a soil contaminant cannot be confirmed. Other than methylene chloride, no VOCs were detected in the background samples.

Acetone was found in nine samples, ranging in concentration from an estimated 6 µg/kg to 150 µg/kg. SW-3 (150 µg/kg) and PP-8-2 (120 µg/kg) had the highest concentrations; the other samples were below 25 µg/kg. All the samples are below the RBC (100,000 µg/kg).

Sample PP-2-1 and SS-18 were the only other sample with VOCs. The analysis from PP-2-1 indicated the presence of 1,2-DCE (1500 µg/kg), PCE (150 µg/kg), and toluene (140 µg/kg). The analysis from PP-C8 measured PCE and estimated toluene at 44 and 5 µg/kg, respectively. The soil samples are below the RBCs for 1,2-DCE, PCE, and toluene at 10,000, 55,000, and 200,000 µg/kg, respectively. The analytical data are presented in Appendix G, Table G-1.

#### 5.1.3.2 SVOCs

A total of seven SVOCs were detected in three soil samples from the PPA.

- Sample PP-6-1 had an estimated concentration of 120 µg/kg of 4-methyl phenol, below RBC concentrations (5,000 µg/kg).
- Sample PP-6-2 had estimated concentrations of phenanthrene (47 µg/kg), fluoranthene (46 µg/kg), and pyrene (43 µg/kg). The field duplicate sample of PP-6-2 did not exhibit contamination by the same compounds, but did contain an estimated concentration of 39 µg/kg of 1,4-dichlorobenzene, below the RBC (120,000 µg/kg).
- Sample PP-12-1 contained estimated concentrations of phenol (410 µg/kg), 4-methylphenol (580 µg/kg), and 2,4-dimethylphenol (420 µg/kg). These levels fall below the RBCs at 610,000, 5,100,000, and 20,000 µg/kg, respectively.

No SVOCs were detected in the background samples. The analytical data are summarized in Appendix G, Table G-2.

### 5.1.3.3 TPH

TPH was detected in 16 of 25 samples collected from the PPA, with concentrations ranging from 40 to 2020 ppm. All but two of these samples (PP-8-2 at 40 ppm and SS-13 at 65.7 ppm) exceeded the 100 ppm VDEQ action level for TPH in soils.

TPH-contaminated samples include PP-2-1, PP-2-2, PP-3-1, PP-3-1FD, PP-5-1, PP-6-1, PP-8-1, PP-8-2, PP-12-1, PP-12-2, PP-14-1, SS-15, SS-16, and the soil samples collected from SW-2 and SW-3. All other PPA samples had no evidence of hydrocarbon contamination.

The primary contaminant appears to be a hydrocarbon that matches the reference standards for compressor oil. However, there appears to be localized contamination by hydrocarbons matching the motor oil, lube oil, and hydraulic jack oil reference standards.

In interpreting the results, ESE evaluated the difference between the TPH concentration in upper and lower sample intervals at each location. Characteristically, a significant drop in concentration was noted from the upper to the lower sample, due to the gradual infiltration of contaminants through the vadose zone by percolation. This relationship was established in the samples from PP-2, PP-3, PP-5, PP-6, PP-8, PP-12, and PP-14.

Where the lower sample (18 to 36 inches) is noted to be above the 100 ppm action level (PP-2-2 and PP-12-2), further sampling was conducted to more accurately delineate the vertical extent of any pockets of soil that may require remediation. The analytical data are presented in Appendix G, Table G-3.

Six soil samples from the three soil borings were collected on 14 and 15 December 1992 pursuant to the revised RI/FS work plan from the PPA. The samples were taken around the known areas of TPH contamination at the 3- to 5-foot and 5- to 7-foot depth intervals (see Figure 5-1). The samples were taken at different depths to determine the vertical extent of TPH contamination.

All six soil samples were found below the detection limits for TPH at the PPA. TPH-contaminated samples included: SB-5-4, SB-5-6, SB-6-4, and SB-6-6. Equipment and field blanks taken were all below detection levels for TPH. The results are summarized in Appendix G, Table G-6.

### 5.1.3.4 TCLP Organics

No TCLP VOC, SVOC, pesticide, or herbicide organics were detected in any of the samples from the PPA. The analytical data are summarized in Appendix G, Table G-4.

#### 5.1.3.5 TCLP Metals

Barium was detected in the extracts from all the samples at concentrations ranging from 79 to 354 µg/kg with a mean value of 204 µg/kg. This range of results is comparable to the background samples, and falls well below TCLP standards (100,000 µg/kg). Arsenic, cadmium, chromium, lead, selenium, and silver were detected in samples from the PPA. Although detected by the instrument, the concentrations were generally below the required detection limits for the analysis and well below the applicable TCLP standards. The analytical data are summarized in Appendix G, Table G-5.

#### 5.1.3.6 IOCs

A total of nine IOCs were detected in the samples collected from the PPA.

- Aluminum was detected in sample SS-18 at 3680 mg/kg and below the RBC (1,000,000 mg/kg) for industrial soil.
- Arsenic was estimated in sample SS-18 at 11.7 mg/kg and below the RBC (310 mg/kg) for industrial soil. Arsenic was above the RBC for arsenic as a carcinogen (1.6 mg/kg).
- Barium was detected in sample SS-18 at 53.8 mg/kg and below the RBC (72,000 mg/kg) for industrial soil.
- Chromium was detected in sample SS-18 at 13.4 mg/kg and below the RBC (5100 mg/kg) for industrial soil.
- Copper was detected in sample SS-18 at 24.3 mg/kg and below the RBC (38,000 mg/kg) for industrial soil.
- Lead was detected in sample SS-18 at 105 mg/kg.
- Manganese was estimated in sample SS-18 at 245 mg/kg and below the RBC (5100 mg/kg) for industrial soil.
- Nickel was detected in sample SS-18 at 10.2 mg/kg and below the RBC (20,000 mg/kg) for industrial soil.
- Vanadium detected in samples SS-18 at 43.3 mg/kg and below the RBC (7200 mg/kg) for industrial soil.

#### 5.1.3.7 Pesticides/PCBs

A total of four pesticides were detected in the samples collected from the PPA.

- Aldrin was estimated in sample SS-18 at 0.0014 mg/kg and below the RBC (0.17 mg/kg) for industrial soil.
- Alpha-chlordane was estimated in sample SS-18 at 0.0031 mg/kg.
- DDD was estimated in sample SS-18 at 0.0038 mg/kg and below the RBC (12 mg/kg) for industrial soil.
- Gamma-chlordane was estimated in sample SS-18 at 0.0049.

#### 5.1.4 Hazardous Materials (HM) Area

##### 5.1.4.1 VOCs

Several VOCs were detected in the soil samples from the HM area. The compounds included: methylene chloride, acetone, 1,2-DCE, 1,1,1-TCA, TCE, 4-methyl-2-pentanone, PCE, and 1,1,2,2-tetrachloroethane (PCA).

- Methylene chloride was detected in 11 samples; however, methylene chloride was detected in the associated blanks, so its presence as a soil contaminant cannot be confirmed.
- Acetone was detected in seven samples with concentrations ranging from an estimated 8 µg/kg in sample HM-4-2 up to a maximum of 450 µg/kg in the soil sample from SW-1. Soil sample HM-3-2 had a detected concentration of 57 µg/kg; the remainder of the samples were below 50 µg/kg. All the samples fall below the RBC (100,000 µg/kg).
- 1,2-DCE was detected in four samples with concentrations ranging from an estimated 5 µg/kg up to a maximum of 20 µg/kg in HM-3-1. Soil samples with 1,2-DCE fall below the RBC (10,000 µg/kg).
- TCA was detected at an estimated concentration of 1 µg/kg in sample HM-10-1 and below the RBC (50,000 µg/kg).
- TCE was detected in sample HM-7-1 at an estimated concentration of 29 µg/kg, but was also detected in an associated blank sample; its presence as a contaminant has not been confirmed. TCE was found below the RBC (260,000 µg/kg).
- PCE was detected in nine samples ranging from an estimated 2 µg/kg up to 32,000 µg/kg in sample HM-9-2. This high level is thought to be due to sample collection in the vicinity of some leaking and damaged drums that were noted during the investigation. However, with the exception of HM-9-2 (32,000 µg/kg), HM-10-1 (150 µg/kg), and HM-9-1 (96 µg/kg); all other values were below the RBC (50

µg/kg). PCE was detected in the analysis for TCLP VOCs in two samples (HM-1 and HM-1 FD); however, the levels of PCE were below the applicable TCLP standard (700 µg/kg).

- PCA was also detected in sample HM-9-2 at an estimated concentration of 30 µg/kg; no other samples had detectable concentrations. PCA was found below the RBC (14,000 µg/kg).

No other VOCs were detected in the background samples. The analytical data are summarized in Appendix G, Table G-1.

#### 5.1.4.2 SVOCs

A total of 10 SVOCs were detected in the samples from the HM area. Concentrations of the compounds in all but one sample were estimated, being below the required detection limits for the analysis. A 2,4-dimethylphenol concentration of 3600 µg/kg was detected in sample HM-2-1 which was below the RBC (20,000 µg/kg) and in three other samples at concentrations below the detection limit for the analysis. Other compounds with estimated concentrations included: 4-methylphenol, 1-4-dichlorobenzene, benzo(a)pyrene, benzo(b)fluoranthene, bis(2-ethylhexyl)phthalate, chrysene, benzo(a)anthracene, pyrene, fluoranthene, and phenol. No SVOCs were detected in the background samples. The analytical data are summarized in Appendix G, Table G-2.

#### 5.1.4.3 TPH

TPH was detected in 18 out of 22 samples collected from the HM area with concentrations ranging from 330 to 2500 ppm. 14 out of the 18 samples exceed the 100 ppm VDEQ action level for TPH contamination in soils.

TPH-contaminated samples included: HM-2-1, HM-2-2, HM-3-1, HM-3-2, HM-4-1, HM-4-1 FD, HM-4-2, HM-5-1, HM-7-1, HM-9-2, HM-10-2, SS-1, SS-4, and SS-8.

The chief constituent appears to be a hydrocarbon that matches the reference standard for compressor oil, but there also appears to be localized contamination by hydrocarbons matching the motor oil, lube oil, and hydraulic jack oil reference standards used in the analysis.

Sample HM-9-1 had unquantifiable hydrocarbon contamination that did not match any of the reference standards used for the analysis, possibly representing a degradation product. All other samples had no evidence of hydrocarbon contamination. In interpreting the results, the difference between the TPH concentration in upper and lower sample intervals at each location was evaluated. Characteristically, a significant drop in concentration was noted from the upper to the lower sample, due to the gradual infiltration of contaminants through the vadose zone by percolation. This relationship between the upper and lower sample intervals

was established in the samples from HM-2, HM-4, HM-5, and HM-7. The lower intervals were found to be more contaminated in the samples from HM-3 and HM-10.

Where the lower sample (18 to 36 inches) is noted to be above the 100 ppm action level (HM-3 and HM-10), further sampling was conducted to more accurately delineate the vertical extent of any pockets of soil that may require remediation. The analytical data are summarized in Appendix G, Table G-3.

Eight soil samples from four soil borings were collected on 14 and 15 December 1992 pursuant to the revised RI/FS work plan from the HM area. The samples were taken around the known areas of TPH contamination at the 3- to 5-foot and 5- to 7-foot depth intervals (see Figure 5-1). The samples were taken at different depths to determine the vertical extent of TPH contamination.

TPH was quantified in only 4 out of 8 samples collected from the HM with concentrations ranging from 16.2 to 47.1 ppm. None of the samples exceeded the 100 ppm VDEQ action level for TPH contamination in soils.

TPH-contaminated samples included: SB-5-4, SB-5-6, SB-6-4, and SB-6-6. Contamination is lower in the deeper borings as expected due to the gradual infiltration of contaminants. The chief constituent appears to be a hydrocarbon that matches the reference standard for diesel fuel. Equipment and field blanks taken were all below detection levels for TPH. The results are summarized in Appendix G, Table G-6.

#### 5.1.4.4 TCLP Organics

In the VOC fraction of the TCLP extract, PCE was detected in samples HM-1 and its field duplicate (6 µg/kg and 8 µg/kg, respectively). The TCLP standard is 700 µg/l.

In the SVOC fraction, 4-methylphenol was detected in the extracts from samples HM-1 and its field duplicate (180 µg/kg and 75 µg/kg, respectively). No pesticides or herbicides were detected. The analytical data are summarized in Appendix G, Table G-4.

#### 5.1.4.5 TCLP Metals

Barium was detected in the extracts from all the samples at concentrations ranging from 228 to 627 µg/kg with a mean value of 353 µg/kg. This range of results is comparable with the results of the background samples and falls well below the applicable TCLP standard (100,000 µg/kg). Arsenic, cadmium, chromium, lead, and selenium were also detected in specific samples from the HM area. Although detected by the instrument, the concentrations were all below the required detection limits for the analysis and well below applicable TCLP standards. The analytical data are summarized in Appendix G, Table G-5.

#### 5.1.4.6 IOCs

A total of nine IOCs were detected in the samples collected from the HM.

- Aluminum was detected in sample SS-17 at 5550 mg/kg and below the RBC (1,000,000 mg/kg) for industrial soil.
- Arsenic was estimated in sample SS-17 at 10.5 mg/kg and below the RBC (310 mg/kg) for industrial soil. Arsenic was above the RBC for arsenic as a carcinogen (1.6 mg/kg).
- Barium was detected in sample SS-17 at 38.1 mg/kg and below the RBC (72,000 mg/kg) for industrial soil.
- Chromium was detected in sample SS-17 at 16.6 mg/kg and below the RBC (5100 mg/kg) for industrial soil.
- Copper was detected in sample SS-17 at 12 mg/kg and below the RBC (38,000 mg/kg) for industrial soil.
- Lead was detected in sample SS-17 at 15.9 mg/kg.
- Manganese was estimated in sample SS-17 at 286 mg/kg and below the RBC (5100 mg/kg) for industrial soil.
- Nickel was detected in sample SS-17 at 7.9 mg/kg and below the RBC (20,000 mg/kg) for industrial soil.
- Vanadium detected in samples SS-17 at 29.7 mg/kg and below the RBC (7200 mg/kg) for industrial soil.

#### 5.1.4.7 Pesticides

A total of four pesticides were detected in the samples collected from the HM.

- beta-BHC was estimated in sample SS-17 at 0.0036 mg/kg.
- DDD was estimated in sample SS-17 at 0.003 mg/kg and below the RBC (12 mg/kg) for industrial soil.
- DDE was estimated in sample SS-17 duplicate at 0.0022 mg/kg and below the RBC (8.4 mg/kg) for industrial soil.
- delta-BHC was estimated in sample SS-17 duplicate at 0.0011.

### 5.1.5 Summary of Soil Contamination

Soil contamination at the site appears to be limited to contamination by VOCs and petroleum hydrocarbons. Some small-scale SVOC, pesticides, and metals contamination (above background but well below applicable TCLP or RBC standards) may also be present.

#### 5.1.5.1 VOCs

Soil contamination by VOCs is generally at a very low level; the most affected area (in terms of type and frequency of compounds) is the HM area (Figures 5-2 and 5-3). Concentrations are generally less than 100 µg/kg for contaminant-specific concentrations. The PCE concentration of 32,000 µg/kg at station HM-9-2 was the only sample above 1000 µg/kg total VOCs and may reflect collection near an obvious spill area. PCE was detected in the TCLP VOC analysis in two samples well below the TCLP standards (700 µg/kg). Acetone (not detected to 650 µg/kg) is a common contaminant in the TA, but was not detected in either of the TCLP samples taken from that area.

The sporadic pattern of contamination within the surface soils reflects the nature of spills at the QADSY. Some areas were affected if subjected to a single large spill or slow leak into the soil, while no significant release occurred in other areas despite having material stored there. Visual soil staining and total VOC concentrations are compared in Figures 4-2 and 4-3. A consistent trend between soil staining and VOC contamination is not apparent.

#### 5.1.5.2 SVOCs

Low soil contamination was primarily found in the TA. Concentrations estimated and detected were below the RBCs for industrial soil.

#### 5.1.5.3 TPH

Soil contamination by TPH is widespread in the TA, PPA, and HM areas; only one EY sample exhibited TPH contamination (Figures 5-4 and 5-5). Concentrations ranged from non-detected to 4400 ppm across the site. A hydrocarbon that closely matches the reference standard for compressor oil is the most common; however, hydrocarbons matching the lube oil, hydraulic jack oil, diesel oil, and motor oil standards are also present. More than 50 percent of the samples collected from the TA, HM, and PPA exceed the VDEQ guidelines (100 ppm) for soil disposal to an industrial or sanitary landfill. Two-thirds of the samples exceed the 50 ppm VDEQ guideline for soil disposal as clean fill. Sampling was performed of the 3- to 5-foot and 5- to 7-foot intervals of the areas of highest TPH concentrations to characterize the vertical extent of contamination. Soil samples collected at the TA and PPA were found to be below the detection limits. The results at four samples indicated low levels of contamination (between 16 and 47 ppm) at these depths at the HM area and are below the VDEQ guidelines (50 ppm) for soil disposal as clean fill. The remaining four soil samples were found to be below the detection limits. Specific portions of each area are likely to be



more affected than others due to their unique histories. However, the soil areas most affected are illustrated in Figures 5-4 and 5-5. A consistent trend between soil staining and TPH contamination is not apparent.

#### 5.1.5.4 TCLP Metals

Two site areas (the northern PPA and the TA) appear to have metals levels that are marginally higher than those noted in the background samples and apparently non-contaminated samples from other site areas. Soils were analyzed using only the TCLP extraction method. Using TCLP methods, none of the samples were found to be contaminated above applicable TCLP standards. Previously existing contaminants within the fill material, specifically, metal, may be impacting soil analysis results because the area was reclaimed using fill material, thought to be dredged from Willoughby Bay. IOCs measured below the RBC for industrial soil.

## 5.2 Groundwater

Unlike the area approach used in the soils investigation, the site will be considered as a whole during discussion and interpretation of the groundwater analytical results. As a fluid medium, groundwater provides the means to transport and redistribute contaminants away from any particular contaminated source area. As a result, it is possible that contaminants from a known or unknown source area can be detected in the groundwater at considerable distances from the original point of entry into the saturated zone.

A knowledge of the groundwater flow direction and gradients lends us the ability to predict, in part, the potential extent and rate of contaminant transport away from known sources. Reciprocally, evaluations of potential source areas can also be made by use of groundwater analytical data. Analytical results from the known potential soil source areas have been discussed in Section 5.1.

During the first part of this investigation, each monitor well location was sampled for VOCs, TPH, and pH; specific samples were also analyzed for IOCs. In the following discussion, the location and interval at which a water sample was collected is identified by a four digit number. The first two digits, SW or DW, represent a shallow (25-foot) or deep (45-foot) well. The third digit, a number, identifies the well location. The last digit, a 1 or 2, identifies a shallow or deep interval within that well. Background wells has the prefix "BG" placed in front of the four-digit number. Shallow wells typically had samples collected from 15-foot and 25-foot intervals and deep wells from a 35-foot interval. The monitor well locations are shown in Figure 5-6.

The second part of the investigation was performed under the Draft Revised RI/FS Work Plan dated November 1992. The groundwater sampling consisted of a hydropunch survey, monitor well installation/sampling, and sampling existing wells for IOCs.

The hydropunch survey involved inserting a narrow-gauge collection tube into the saturated portion of the aquifer for a "one-time" sample. The tube was withdrawn following sample collection. A total of 76 samples (including QA/QC samples) were analyzed on a portable Photovac I gas chromatograph/photoionization detection (GC/PID) for the target analytes TCE, PCE, and 1,2-DCA.

ESE used EPA Method 3810 (modified) for GC analysis. This method involves extracting VOCs from the samples by allowing the sample VOCs to volatilize in the headspace of a vial. Headspace gas is withdrawn in a gas-tight syringe and injected into the portable GC/PID for analysis. The results were compared to standards analyzed on the GC, which allowed VOC quantification in the hydropunch samples (standards are analyzed in the same manner as the samples).

Eight wells were also installed during this second part of the RI investigation; and then sampled following development, equilibration, and purging. The samples were shipped to the ESE laboratory for analysis of PCE, TCE, and 1,2-DCA. The last round of the RI investigation included groundwater analysis for VOCs, SVOC, pesticides/PCBs, IOCs, and cyanide.

Background groundwater samples were collected and analyzed for VOCs and pH at DW-2 and DW-4 and VOCs, TPH, pH, and IOCs.

### 5.2.1 VOCs

A total of 11 VOCs were detected in the groundwater samples collected from the QADSY monitor wells. The compounds and their range of concentrations are presented in Table G-1. The analytical data are summarized in Appendix G, Table G-7.

The presence and concentration of groundwater contaminants noted in the samples collected from the monitor well network can be used to define the plume emanating from a potential source area(s), due to the groundwater flow and physical properties of the contaminants concerned.

Typically, monitor wells installed in the water table beneath active source areas exhibit the highest level of VOC contamination. However, many VOCs are readily soluble and can be easily transported by the groundwater in the direction of flow. It is not uncommon to see a degree of radial migration from a source area due to the spread of contaminants within the vadose zone, prior to percolation into the water table, followed by the radial spread of contaminants due to diffusion and contaminant densities relative to water. The relative mobility of each contaminant in soil and groundwater is a function of its physical properties. The concentrations of total VOCs in the monitor well samples are presented in Table G-2. VOCs can only be compared to VDEQ regulatory standards for surface water; no groundwater standards for VOCs have been set.

#### 5.2.1.1 Tetrachloroethene

The first sampling effort revealed PCE in 10 samples ranging in concentration from an estimated 3 µg/l up to 4800 µg/l. The most impacted samples were those from SW-2-1 (4800 µg/l) and SW-2-2 (3700 µg/l). SW-2 is located directly beneath and downgradient of the HM area and would be expected to exhibit the highest concentrations. Lower concentrations of 220 µg/l and 180 µg/l were observed in SW-1-1 and SW-1-2, respectively. SW-1 is also located in the HM area. Significant concentrations were also noted in SW-6-2 (91 µg/l) and GW-1-1 (14 µg/l), both downgradient from the HM area. Lesser concentrations were noted in samples DW-1 (3 µg/l, estimated, indicating that the downward extent of the plume may be close to this level) and in SW-5-1, which may be the result of a smaller, unknown spill in the TA. The monitor wells installed in January 1993 yielded low PCE concentrations. PCE ranged from 1.17 (DW-7-D) to 68.4 µg/l (DW-8-S). The last round only detected PCE from one location (DW-8) at 75 µg/l. Results are summarized in Appendix G, Table G-8. The VDEQ standard for PCE in surface water (3519 µg/l) was exceeded by both samples from SW-2; other samples fall below the standard.

The hydropunch survey detected PCE at 15 locations (1.6 µg/l to 452 µg/l). The highest concentrations were northwest of the QADSY area and typically at a depth of 15 feet. Hydropunch results are summarized in Table G-3. None of the hydropunch samples exceeded the VDEQ PCE standard.

#### 5.2.1.2 Trichloroethene

The first sampling effort indicated TCE in 13 samples, ranging from an estimated 2 µg/l up to 560 µg/l. Again, the samples from SW-2-1 (560 µg/l) and SW-2-2 (490 µg/l) were most impacted, and the samples from SW-1-1 (66 µg/l, estimated) and SW-1-2 (34 µg/l, estimated) had moderate concentrations. Downgradient samples SW-6-1 and GW-1-1 (47 and 39 µg/l, respectively) reflect the formation of the contaminant plume to the west and southwest. Interestingly, TCE was not noted in the deep samples from either well. The concentration observed in the sample from DW-1 may represent the lower limit of the TCE plume at the site. TCE concentrations in samples from SW-3-2 (6 µg/l), SW-4-1 (9 µg/l), SW-4-2 (10 µg/l), and SW-5-1 (2 µg/l, estimated) may reflect smaller, undefined spills across the area. The wells installed in January 1993 yielded low TCE concentrations, ranging from 3.03 (SW-9-10) to 37.3 µg/l (DW-7-D). Results are summarized in Appendix G, Table G-8. The VDEQ surface water standard for TCE in surface water (807 µg/l) was not exceeded in any of the samples.

The hydropunch survey detected TCE in 55 samples ranging from less than 2.0 µg/l to 1371 µg/l (HP-15-35). The results are summarized in Table G-3. The highest concentrations were found due west and northwest of the QADSY. Also noted was the predominance of high concentrations found at the 15-foot and 35-foot sampling depth interval, generally decreasing at successively greater depths. Samples HP-11-35 and HP-15-35 exceeded the VDEQ TCE

surface water standard (807 µg/l). Only two groundwater samples detected TCE during the sampling last round: DW-7 and DW-8 at 20 and 18 µg/l, respectively.

#### 5.2.1.3 1,1,1-Trichloroethane

1,1,1-TCA was detected in 11 samples ranging from an estimated 1 µg/l up to 1100 µg/l. Samples SW-1-1 and SW-1-2 were most impacted at 1100 and 690 µg/l, respectively. This marks a change from the TCE and PCE results, which were highest in SW-2. It is not clear if previous storage practices may have dictated the distribution of contaminants (i.e., if TCE/PCE was placed in the east of the HM area and 1,1,1-TCA to the north). Significant concentrations were noted, however, in samples SW-2-1 and SW-2-2 (390 and 270 µg/l). Lower concentrations were observed in samples SW-4-1 (3 µg/l, estimated), SW-4-2 (3 µg/l, estimated), SW-6-1 (1 µg/l, estimated), DW-1 (3 µg/l, estimated), GW-3-1 (4 µg/l, estimated), and GW-3-2 (3 µg/l estimated). No VDEQ surface water standard exists for 1,1,1-TCA.

#### 5.2.1.4 1,2-Dichloroethane

Sampling for 1,2-DCA was performed during the second sampling effort. 1,2-DCA was detected in one hydropunch sample (HP-8-35) at a level of 460 µg/l (Table G-3). No 1,2-DCA was detected in the wells installed during the second sampling effort. The VDEQ surface water standard for 1,2-DCA (990 µg/l) was not exceeded by any samples.

#### 5.2.1.5 1,2-Dichloroethene

1,2-DCE was detected in 10 samples ranging from 22 to 500 µg/l; the highest concentration was in downgradient sample GW-1-1. Significant concentrations were also observed in onsite samples SW-1-1 (230 µg/l), SW-1-2 (130 µg/l), SW-2-1 (430 µg/l), and SW-2-2 (400 µg/l). The other downgradient well samples SW-6-1, SW-6-2, DW-7, and SW-9 contained 50, 120, 22, and 32 µg/l (estimated), respectively. There is no VDEQ surface water standard for 1,2-DCE.

#### 5.2.1.6 1,1-Dichloroethane

1,1-DCA was detected in 10 samples ranging from 2 µg/l (estimated) up to 540 µg/l. The highest concentrations were observed in onsite well samples SW-2-1 (520 µg/l) and SW-2-2 (540 µg/l). Significant concentrations were also observed in samples SW-1-1 (290 µg/l), SW-1-2 (240 µg/l), SW-4-1 (13 µg/l), SW-4-2 (21 µg/l), SW-6-1 (13 µg/l), BGSW-8-1 and BGSW-8-2 (each with 4 µg/l, estimated), GW-1-1 (21 µg/l), GW-3-1 (2 µg/l, estimated), and GW-3-2 (2 µg/l, estimated). As a result of the second sampling effort, 1,1-DCA was detected in three wells, ranging from 2.5 µg/l (shallow SW-10) to 21.9 µg/l (DW-3D). No VDEQ surface water standard exists for 1,1-DCA. The last sampling effort detected 1,1-DCA in DW-3 only (9 µg/l, estimated).

#### 5.2.1.7 Acetone

Acetone was detected in 22 samples and was the most ubiquitous VOC contaminant. Acetone is a common laboratory contaminant, and several samples were flagged by the data validator as being influenced by laboratory contamination.

Concentrations ranged from 7 µg/l (estimated) up to 1300 µg/l. The highest concentrations were observed in samples from wells within the HM area: SW-1-1 (1300 µg/l), SW-1-2 (830 µg/l), SW-2-1 (960 µg/l), and SW-2-2 (920 µg/l). Significant concentrations were also observed in SW-6-2 (460 µg/l, estimated), SW-7-2 (78 µg/l), GW-1-1 (110 µg/l), and GW-4-1 (170 µg/l). Lower estimated concentrations were noted in SW-4-1 (7 µg/l) and SW-7-1 (9 µg/l). The remainder of the detected concentrations were flagged as probably being the result of laboratory contamination during the analysis. The concentration observed in BGDW-2 (160 µg/l) is likely the result of residual contamination from the drilling mud used to install the deep wells. An analysis of the drilling mud detected 690 µg/kg acetone.

The pattern of higher onsite levels, with corresponding lower levels in downgradient wells, is repeated with acetone, confirming its presence as a site contaminant. No VDEQ surface water standard exists for acetone.

#### 5.2.1.8 1,1-Dichloroethene

1,1-DCE was detected in 11 samples ranging from an estimated 1 µg/l up to an estimated 140 µg/l; the highest concentration was noted in SW-2-1. 1,1-DCE was also observed in SW-1-2 (97 µg/l, estimated), SW-1-1 FD (33 µg/l), SW-4-1 (28 µg/l), SW-4-2 (41 µg/l), SW-5-2 (1 µg/l, estimated), SW-6-1 (13 µg/l), BGSW-8-1 and BGSW-8-2 (6 and 4 µg/l, estimated), BGDW-2 (3 µg/l, estimated), and DW-1 (3 µg/l, estimated).

Again, the highest concentrations were observed in onsite wells, with lower concentrations in the downgradient wells. 1,1-DCE detected in SW-4 and SW-5 may be the result of smaller spills in the TA. 1,1-DCE was also observed at low concentrations in all of the background samples; no explanation can be offered for this. No VDEQ surface water standard exists for 1,1-DCE.

#### 5.2.1.9 Carbon Tetrachloride

Carbon tetrachloride was detected in three samples, all from well SW-1. An estimated 120 µg/l was observed in SW-1-1 (72 µg/l in its field duplicate), and an estimated 84 µg/l was observed in sample SW-1-2. Because it was not observed in other wells, its presence may be the result of localized contamination around SW-1. All three samples are above the VDEQ standard for carbon tetrachloride in surface water (45 µg/l).

#### 5.2.1.10 Methylene Chloride

Methylene chloride was detected in 21 samples ranging in concentration from 4 to 780 µg/l. As with acetone, methylene chloride is a common laboratory contaminant, and many of the samples were flagged by the data validator as being impacted by laboratory contamination. Only the following samples were not flagged and are considered usable in this report: SW-3-2 FD (9 µg/l), SW-4-1 (9 µg/l), and SW-7-1 (10 µg/l). No VDEQ surface water standards are set for methylene chloride.

#### 5.2.1.11 Chloroform

Chloroform was detected in three samples: SW-3-1 (1 µg/l, estimated), BGDW-2 (19 µg/l), and DW-1 (60 µg/l). The presence of chloroform in samples from the two deep wells may be due to the use of drilling muds in installing the wells; analysis of the mud detected 270 µg/l of chloroform (Table G-4). The VDEQ standard for chloroform in surface water (4700 µg/l) was not exceeded.

#### 5.2.1.12 Bromodichloromethane

Bromodichloromethane was detected in three samples: SW-1-1 (120 µg/l, estimated), SW-1-2 (120 µg/l, estimated), and DW-1 (4 µg/l, estimated). The presence of the compound in the sample from DW-1 may be attributed to residual contamination from the mud used in installing the well (Table G-4). Its presence in samples SW-1-1 and SW-1-2 (but not the duplicate sample from SW-1-1) may be due to a localized spill. No VDEQ surface water standards exist for bromodichloromethane.

#### 5.2.1.13 Extent of VOC Contamination

By interpreting the total VOC concentrations in each well, it is possible to evaluate the approximate extent and concentration of contamination (the contaminant plume), regardless of the specific mobility of individual compounds. The same method is applicable to individual compounds by using the concentrations noted in each well to determine the areal extent of contamination. The areal or two-dimensional extent of the contaminant plumes for each compound is presented in Figures 5-7 through 5-20.

The approximate vertical component of the contaminant plume can also be inferred by noting the difference in concentration between specific compounds in samples collected in the upper portion of the water table, and at greater depth within the saturated zone from each location. The vertical extent for total VOCs and specific chemicals can be seen in Figures 5-22 through 5-27. (Figure 5-21 indicates the line of section for Figures 5-22 through 5-28.)

The hydropunch survey shows a pattern from which contaminant plumes can be inferred. The general trend in VOC contamination is movement west and northwest, toward the sea wall on the Elizabeth River. As noted on Figures 5-29 and 5-30 the concentrations of PCE and TCE

at 15 feet in depth are highest around the fence between the northwest corner of the QADSY storage yard and the adjacent parking lot and near the sea wall. These two high-concentration areas are also distinguishable at 25 feet in depth for PCE contamination (Figure 5-31). At 25, 35, and 45 feet (Figures 5-32 through 5-34) with respect to TCE contamination, the two areas of higher concentration merge and one large plume can be inferred. At depths of 55 and 65 feet, the high concentration areas for TCE are once again separate (Figures 5-35 and 5-36).

Figure 5-6 indicates the location of the TCE concentration cross-sections. Cross-sections A-A' and B-B' (Figures 5-37 and 5-38) show the highest concentration at approximately 300 feet east of the bulkhead and 35 feet below surface. Cross-section B-B' presents two high concentration values.

TCE contamination was the most ubiquitous, followed by PCE; very few detections of 1,2-DCA were noted. The dispersal of high concentration readings throughout the area of study suggest many source points for the contamination.

### 5.2.2 TPH

A total of 25 groundwater samples (including field duplicates) were analyzed for TPH. Of these, 11 were found to have detectable TPH concentrations: SW-1-1, SW-1-1 FD, SW-2-1, SW-5-1, SW-5-2, SW-6-1, SW-6-2, SW-7-1, SW-7-2, BGSW-8-1, and BGSW-8-2. The remaining samples had no evidence of TPH contamination. With the exception of SW-1-2, TPH was detected in all of the samples below the 1 ppm VDEQ standard for TPH in groundwater. The concentration of TPH in SW-1-2 was between 1 and 5 ppm (the concentration could not be refined any further). The analytical data are summarized in Appendix G, Table G-9.

### 5.2.3 IOCs

During the first sampling round, groundwater samples were collected from the deeper (25-foot) interval at nine wells (SW-1, SW-2, SW-3, SW-4, SW-5 and background well SW-8 in October 1990 and existing wells GW-1, GW-3, and GW-4 in January 1991) and analyzed for IOCs. The same analyses were performed for samples taken in October 1992. Filtered and unfiltered samples of SW-2, SW-5, SW-8, DW-1, DW-2, and one surface water sample from Willoughby Bay were taken at this time. Filtered and unfiltered samples from DW-3 through DW-8, SW-9, and SW-10 were also collected for IOCs in May 1995.

Results of the first sampling were as follows:

- A total of 10 metals were detected in the samples including: antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, and zinc.
- A number of analytes exceeded VDEQ standards for groundwater in the samples from three wells: SW-2, SW-4, and SW-5.

- The VDEQ groundwater standard for arsenic (50 µg/l) was exceeded in two samples: SW-2-2 (171 µg/l) and SW-5-2 (337 µg/l).
- The VDEQ groundwater standard for cadmium (0.4 µg/l) was exceeded in four samples: SW-2-2 (8 µg/l), SW-4-2 (15 µg/l), SW-5-2 (96 µg/l), and GW-4-2 (8 µg/l).
- The VDEQ groundwater standard for chromium (50 µg/l) was exceeded in four samples: SW-2-2 (281 µg/l), SW-4-2, (206 µg/l), SW-5-2 (1120 µg/l), and GW-4-2 (63 µg/l).
- The VDEQ groundwater standard for lead (50 µg/l) was exceeded in samples SW-2-2 (116 µg/l), SW-4-2 (102 µg/l), and SW-5-2 (516 µg/l).
- The VDEQ groundwater standard for mercury (0.05 µg/l) was exceeded in samples SW-2-2 (0.22 µg/l) and GW-4-2 (0.3 µg/l).
- The VDEQ groundwater standard for zinc (50 µg/l) was exceeded in three samples: SW-2-2 (354 µg/l), SW-4-2 (416 µg/l), SW-5-2 (1580 µg/l), and GW-4-2 (101 µg/l).

The results of the second sampling in December 1992 are as follows:

- A total of seven metals were detected, including mercury, arsenic, cadmium, silver, chromium, antimony, and zinc.
- Only two samples (filtered SW-5 and DW-2 and unfiltered duplicate) exceeded VDEQ standards for groundwater.
- The VDEQ groundwater standard for mercury (0.05 µg/l) was exceeded in sample SW-5 (filtered) at a level of 0.140 µg/l.
- The VDEQ groundwater standard for cadmium (0.4 µg/l) was exceeded in one sample (the field duplicate of well DW-2, sample FD-1, unfiltered) at a level of 0.5 µg/l. The other sample at DW-2 (unfiltered) measured <0.1 µg/l.
- Antimony was detected in all samples collected at concentrations over 50 µg/l. No VDEQ groundwater standards currently exist for antimony in groundwater.

The results of the last sampling in May 1995 are as follows:

- The VDEQ groundwater standard for cadmium (0.4 µg/l) was exceeded in five samples: filtered DW-3 (5.7 µg/l), unfiltered and filtered DW-5 (7.3 and 8 µg/l), unfiltered and filtered DW-6 (5.8 and 5 µg/l), unfiltered and filtered SW-9 (4.4 and 6 µg/l), and unfiltered SW-10 (4 µg/l).



The results for the first sampling event are presented graphically in Figure 5-28. The analytical data are summarized in Appendix G, Table G-10. The analytical data for the second event are summarized in Appendix G, Table G-11.

The analytical results of the first sampling suggest that groundwater quality was impacted by IOCs in the vicinity of wells SW-2, SW-4, SW-5, and GW-4. Subsequent sampling showed low levels of metals, except SW-5, which exceeded the standard for mercury. Background sample analyses indicate low or non-detectable levels of the analytes of concern. Sample results appear to indicate that groundwater quality, with respect to IOCs, may be improving.

#### **5.2.4 SVOCs**

Groundwater samples collected in May 1995 indicated that one SVOC, bis(2-ethylhexyl) phthalate was estimated in DW-3 (8 µg/l), DW-4 (6 µg/l), DW-5 (4 µg/l), DW-6 (8 µg/l), DW-7 (1 µg/l), SW-9 duplicate (3 µg/l), and SW-10 (2 µg/l) and detected in SW-9 (54 µg/l).

#### **5.2.5 Summary of Groundwater Contamination**

Analytical data suggest significant groundwater contamination onsite and offsite by VOCs, and, to a lesser extent, TPH and metals. The analytical data for VOCs in the TA and the results of the hydropunch survey show no discernable consistency; this may be a reflection of past area use for loading and storage where no large, long-term sources were developed.

The VDEQ has developed concentration standards for certain constituents in groundwater. However, no groundwater standards have been developed for the VOCs of concern at the QADSY. The VDEQ has standards for surface water, in regard to human health and toxicity to aquatic life. In particular, the standards for nonpublic surface water supplies have been chosen for comparison to VOC concentrations in groundwater samples from the QADSY because groundwater standards are not available (Table 5-5). Although the surface water standards may be more stringent than necessary for groundwater, they are used as a point of reference. The nonpublic water supply standards were chosen for comparison because such water use most closely parallels water use at the QADSY (i.e., the aquifer is not used for potable water and potential contaminant migration is not expected to affect any drinking water wells).

##### **5.2.5.1 VOCs**

###### **Shallow Wells**

In the shallow wells, VOC contamination is most severe beneath the HM area and the northern-most portion of the PPA. Total VOCs in the HM area peak at 7800 µg/l in SW-2, with contamination by PCE, TCE, 1,1,1-TCA, 1,2-DCE, 1,1-DCE, 1,1-DCA, carbon tetrachloride, and acetone. A similar list of contaminants is observed in monitor well SW-1, 150 feet to the north. Many of the same contaminants are also observed (in much lower

concentrations) in SW-6 and GW-1 to the west and southwest (total VOCs, 671 and 718  $\mu\text{g/l}$ , respectively), but not in SW-3 (total VOCs, 13  $\mu\text{g/l}$ ) to the southeast of SW-2, indicating flow and the formation of a plume to the west. The only contaminant noted in the shallow background well (SW-8) is 1,1-DCE at estimated concentrations of 4  $\mu\text{g/l}$  in the shallow (10-15 feet) portion and 41  $\mu\text{g/l}$  in the deeper (20-25 feet) portion. No VDEQ groundwater standards have been developed for any of these compounds; VDEQ standards for surface water (nonpublic supply) are exceeded by TCE and PCE in SW-2 (Table 5-5). TCE surface water standards are exceeded in HP-11-35 and HP-15-35. Carbon tetrachloride exceeds the standard in SW-1 and SW-2. No standards are in place for 1,2-DCE, 1,1-DCA, acetone, 1,1-DCE, methylene chloride, and bromodichloro-methane. Shallow wells outside the QADSY (SW-9 and SW-10) show only low levels of PCE and TCE.

Smaller plumes may have formed beneath the TA as identified by the concentrations of total VOCs in SW-4 and SW-5 (60 and 76  $\mu\text{g/l}$ , respectively), but the lack of any discernible pattern or contaminant plume and the absence of similar contaminants, even at low levels, in downgradient well SW-7 suggest that these plumes are small and confined to low levels beneath the TA only.

#### Deep Wells

In the deep background well (DW-2), VOCs total 182  $\mu\text{g/l}$ . Methylene chloride is excluded because it is possibly the result of laboratory contamination. Acetone (160  $\mu\text{g/l}$ ), chloroform (19  $\mu\text{g/l}$ ), and 1,1-DCE (3  $\mu\text{g/l}$  estimated) were also detected.

VOCs total 75  $\mu\text{g/l}$  in DW-1. Contaminants include methylene chloride (8  $\mu\text{g/l}$ ), 1,1-DCE (3  $\mu\text{g/l}$ , estimated), chloroform (60  $\mu\text{g/l}$ ), 1,1,1-TCA (3  $\mu\text{g/l}$ , estimated), bromodichloromethane (4  $\mu\text{g/l}$ , estimated), TCE (2  $\mu\text{g/l}$ , estimated), and PCE (3  $\mu\text{g/l}$ , estimated). Methylene chloride is likely the result of laboratory contamination. With the exception of bromodichloromethane, all of these compounds are found in higher concentrations in the shallower nested well SW-2.

No VDEQ groundwater standards exist for any of the listed compounds. There are no VDEQ proposed surface water standards for 1,1-DCE or bromodichloromethane; the other compounds do not exceed their proposed standards (Table 5-5).

Two deep wells (DW-1 and DW-2) were installed using drilling mud. A laboratory analysis of the mud indicated chloroform (270  $\mu\text{g/l}$ ), acetone (690  $\mu\text{g/l}$ ), and bromodichloromethane (52  $\mu\text{g/l}$ , estimated). It is likely that residual drilling fluids left in the formation following well installation may have impacted the groundwater samples collected a few days later. Even following prolonged development and purging, it is often difficult to remove all traces of well installation fluids. The drilling mud composition may explain the concentrations of chloroform, acetone, and bromodichloromethane in wells DW-1 and DW-2 (Table 5-4).

Deep wells (DW-3 through DW-8) drilled during January 1993 outside of the QADSY do not show significant levels of the contaminants of concern.

#### 5.2.5.2 TPH

Although detected by the laboratory, the TPH detected in the water samples does not match the reference standards or "fingerprints" used in the analysis. Subsequent biodegradation of previously existing hydrocarbons may have altered the characteristics of those compounds. Groundwater TPH concentrations range from less than 1 ppm up to a value between 1 and 5 ppm, but are not detected in any of the wells located in the PPA (SW-2, SW-3, and SW-4). The VDEQ groundwater standard for TPH in groundwater is 1 ppm. It is difficult to draw conclusions regarding the impact, fate, and transport of hydrocarbons in the groundwater; however, they appear to be minimal.

#### 5.2.5.3 IOCs

Groundwater contamination by IOCs is apparent beneath the TA, the northwestern part of the and the vicinity of GW-4. During the first sampling event, VDEQ groundwater standards were exceeded for cadmium, chromium, and zinc in wells SW-2, SW-4, SW-5, and GW-4 and for arsenic in wells SW-2 and SW-5. The standard for lead was exceeded in wells SW-2, SW-4, and SW-5. SW-5 exceeded the standard for mercury during the second sampling event. The cadmium groundwater standard was exceeded in well DW-2 (FD) during the second sampling event. No metal standards are exceeded in the background well or from the second round of sampling except cadmium and mercury (discussed above). IOCs were not collected during January 1994 due to the results of the second round of sampling. The cadmium groundwater standard was exceeded in DW-3, DW-5, DW-6, SW-9, and SW-10 during the last sampling event. Groundwater quality may be improving with respect to IOCs.

### 5.3 Sediment

Sediment samples were taken on 21 January 1993 from storm drainage conduits in the QADSY. Sample SD-1 was collected south of monitor well SW-4, and sample SD-2 was collected from the storm drain in front of the QADSY trailer (Figure 5-1). Samples from the two drains were analyzed for IOCs, TCL pesticides and PCBs, TPH, and TCL VOCs.

### 5.3.1 IOCs

Few guidelines or regulatory standards exist to compare analysis results with respect to total metal contamination in soil. The EPA Region V office has established guidelines for pollutional classification of Great Lakes Harbor Sediments, and analytical results were compared to these (Fitchko, 1989). Results were also compared to element concentrations in soils in the eastern United States (Shacklett and Boerngen, 1984), and Federal Register Proposed Rules 20 May 1992 for concentration-based exemption criteria for hazardous waste listing, and Federal Register 27 July 1990, for corrective-action criteria (USEPA, 1990). Comparison with the EPA Region V Guidelines may be the most appropriate since it specifically addresses sediments.

The concentration of all IOCs analyzed (Appendix G, Table G-12) were well within the range of concentrations for natural soils, except lead concentrations in SD-2, which were slightly above the range. None of the IOCs were detected in concentrations exceeding the federal guidelines or corrective action criteria.

When analytical results were compared to the USEPA, Region V guidelines, the sediments are considered moderately polluted for the following parameters:

- Arsenic was detected in sample SD-2 at a level of 5.64 mg/kg. The standard for moderately polluted sediments is 3-8 mg/kg.
- Barium was detected in sample SD-1 at a level of 24.2 mg/kg. The standard for moderately polluted sediments is 20-60 mg/kg.
- Chromium was detected in sample SD-1 at a level of 32.4 mg/kg. The standard for moderately polluted sediments is 25-75 mg/kg.
- Manganese was detected in sample SD-2 at a level of 322 mg/kg. The standard for moderately polluted sediments is 300-500 mg/kg.

The sediments are considered heavily impacted for the following elements:

- Barium was detected in sample SD-1 at a level of 68.5 mg/kg. Heavily polluted sediments are those with concentrations greater than 60 mg/kg.
- Copper was detected in sample SD-1 at a level of 120 mg/kg. Heavily polluted sediments are those with concentrations greater than 50 mg/kg.
- Iron was detected in sample SD-2 at a level of 26,400 mg/kg. Heavily polluted sediments are those with concentrations greater than 25,000 mg/kg.

- Lead was detected in sample SD-1 and SD-2 at levels of 105 and 350 mg/kg. Heavily polluted sediments are those with concentrations greater than 60 mg/kg.
- Zinc was detected in sample SD-1 at a level of 225 mg/kg. Heavily polluted sediments are those with concentrations greater than 200 mg/kg.

### 5.3.2 Pesticides/PCBs and VOCs

TCL pesticide/PCB analysis revealed concentrations of the pesticides chlordane and DDT homologues (DDE, DDD). Analytical results are found in Appendix G, Table G-12. Sediments from SD-1 had a concentration of alpha-chlordane of 17,600 and gamma-chlordane of 15,900 µg/kg. For comparison it is noted that these levels exceed the Total Threshold Limit Concentration (TTLC) of California's Hazardous Waste Control Act guidelines for identification of hazardous materials. The guideline for chlordane is 2500 µg/kg. DDT homologues were detected in both samples, but neither exceeded the guideline levels.

These pesticides were not detected previously in the TCLP analysis run on soil borings from the QADSY, suggesting that these contaminants may have originated in some other area of the base.

TCL VOCs were found below the detection limits for both sediment samples. Analytical results are found in Appendix G, Table G-12.

### 5.3.3 TPH

Both sediment samples were analyzed for TPH as gasoline and as diesel. TPH as diesel was detected at a level of 299 µg/g in SD-1 and 58.3 µg/g in SD-2. The sample from SD-1 exceeds the VDEQ standard for disposal in an industrial or sanitary landfill. This finding is consistent with the sampling locations being near the PPA where TPH was noted, although it matched the lube oil standard and not the diesel standard. The soil samples collected in December 1992 did indicate TPH as diesel in the northeast corner of the fenced yard. Analytical results are found in Appendix G, Table G-12.

## 5.4 Surface Water

One surface water sample was collected from the Elizabeth River between Piers 10 and 11 west of the QADSY in October 1992. The surface water sample was analyzed for IOCs. Only antimony was detected in the filtered and unfiltered samples at a concentration over 300 µg/l (Appendix G, Table G-11). No standards currently exist for antimony in surface water.

**Table 5-1. VOCs Detected in QADSY Area Monitor Wells**

<b>Compound</b>	<b>Range of Concentrations</b>
Methylene chloride	4 - 780 µg/l (also detected in blanks)
Acetone	ND - 1300 µg/l
1,1 - Dichloroethane (1,1-DCA)	ND - 540 µg/l
1,1 - Dichloroethene (1,1-DCE)	ND - 140 µg/l
1,2 - Dichloroethene (1,2-DCE)	ND - 430 µg/l
Chloroform	ND - 60 µg/l
1,1,1 - Trichloroethane (1,1,1 - TCA)	ND - 1100 µg/l
Carbon tetrachloride	ND - 120 µg/l
Bromodichloromethane	ND - 120 µg/l
Trichloroethane (TCE)	ND - 560 µg/l
Tetrachloroethane (PCE)	ND - 4800 µg/l

ND = Compound was analyzed for but not detected.

Table 5-2. Total VOCs in Groundwater

Monitor Well/Sample No.	Interval (from Surface)	Total VOCs ( $\mu\text{g/l}$ )*
SW-1-1	15'	3446
SW-1-2	25'	2395
SW-2-1	15'	7800
SW-2-2	25'	6320
SW-3-1	15'	13
SW-3-2	25'	15
SW-4-1	15'	60
SW-4-2	25'	84
SW-5-1	15'	76
SW-5-2	25'	67
SW-6-1	15'	130
SW-6-2	25'	671
SW-7-1	15'	9
SW-7-2	25'	78
BGSW-8-1	15'	4
BGSW-8-2	25'	41
DW-1	35'	75**
BGDW-2	35'	182**
GW-1-1	15'	718
GW-1-2	25'	ND
GW-3-1	15'	6
GW-3-2	25'	11
GW-4-1	15'	1
GW-4-2	25'	7

\* Values exclude methylene chloride, which was detected in sample blanks.

\*\* Results could be affected by drilling fluid contamination; chloroform and acetone were detected in significant concentrations in the mud used to install the well.

TABLE 5-3  
RESULTS OF HYDROPUNCH SURVEY

PARAMETER	TCE (ug/l)	PCE (ug/l)	1,2-DCA (ug/l)	pH	CONDUCT. (mhos/cm)	TEMP. (Celsius)
WELL						
HP-5-15	<1	<1	<100	7.74	2020	16.5
HP-5-25	<1	<1	<100	7.98	4680	13.8
HP-11-15	299	26.9	<500	7.29	1280	15.5
HP-11-25	233	13.5	<1000			
HP-11-35	866	<10	<1000	8.1	2960	16.4
HP-11-45	57.7	<10	<1000	7.48	1565	17
HP-11-55	32.7	<1	<100	7.43	2540	17.9
HP-11-65	18.7	<1	<100	7.33	2490	17.3
HP-11-75	<1	<1	<100	7.39	2980	17.9
HP-12-15	8.1	<1	<500			
HP-12-25	<1	<1	<100	7.47	1017	17.2
HP-13-15	82.7	10.9	<100	7.72		17.1
HP-13-25	3.5	<1	<100	7.49	1190	14.1
HP-13-35	<1	<1	<1000	7.29	2660	18.9
SW-3-S	4.1	<1	<100			
SW-3-D	3.7	<1	<100			
SW-7	114	<1	<100			
SW-7-S	141	<1	<100			
SW-7-D	167	<1	<100			
HP-14-15	312.8	425.2	<4000			
HP-14-25	18.9	4.3	<100	7.81	446	17.7
HP-14-35	9.6	<1	<100			
HP-14-50	<1	<1	<100			
HP-15-15	233	155	<100	7.3	130	15.6
HP-15-25	339	<1	<100	7.93	510	17.1
HP-15-35	1371	<1	<100	8.09	181	15.6
HP-15-45	3.1	<1	<100	7.03	2410	15.2
HP-15-55	2.7	<1	<100	9.8	977	15.2
HP-16-15	<1	<1	<100			
HP-16-25	<1	<1	<100	7.82	360	16.1
HP-17-15	73	74	<1000	7.37	253	16.1
HP-17-25	27	19	<1000	7.5	1430	14.5
HP-17-35	<1	<1	<100	6.9	2280	18.2
HP-18-15	80.7	179	<100	7.48	150	16.3
HP-18-25	<1	<1	<100			
HP-10-15	13	<1	<250	7.18	414	16.9
HP-10-15(DUP)	12	<1	<250			
HP-10-25	53	10.5	<250	7.62	871	13.2
HP-10-35	3.3	<1	<250	6.89	2490	17.9
HP-10-45	<1	<1	<250	6.97	2510	16.9



TABLE 5-3  
RESULTS OF HYDROPUNCH SURVEY

PARAMETER WELL	TCE (ug/l)	PCE (ug/l)	1,2-DCA (ug/l)	pH	CONDUCT. (mhos/cm)	TEMP. (Celsius)
DW-3-55	<5	<5	<500	7.75	339	11.4
DW-3-65	<1	<1	<100	7.52	2740	11.2
HP-6-15	308	452	<4000	6.8	798	12.7
HP-6-25	2.2	1.6	<100	7.72	500	9.6
HP-6-25 (DUP)	2.9	1.9	<100			
HP-6-35	8.4	<1	<100	7.85	1170	14.7
HP-6-35(DUP)	5.5	<1	<100			
HP-8-15	22.3	<3	<300			
HP-8-25	2	<1	<100	7.27	3950	16
HP-8-25(DUP)	2	<1	<100			
HP-8-35	4.7	1.6	460	7.8	240	15
HP-2-20	73.5	<10	<1000	7.48		7.2
HP-2-35	25.7	<1	<100	7.84	281	12.4
HP-2-45	20.5	<10	<100			
HP-2-65	41.8	<1	<100			
HP-7-15	124	<1	<100			
HP-7-25	80.8	<1	<100	7.87	210	16.9
HP-7-35	65	<1	<100	7.8	339	12
HP-7-45	25.1	<1	<100	7.74	200	10.3
HP-7-45(DUP)	35.4	<1	<100			
HP-7-55	<1	<1	<100	7.5	1724	12.5
HP-7-55(DUP)	<1	<1	<100			
HP-3-15	25.1	<1	<100	7.04	103	10.1
HP-3-25	<1	<1	<100	7.72	3430	10.5
HP-4-15	<2	<2	<200	7.59		12.2
HP-4-15(DUP)	<2	<2	<200			
HP-4-25	<1	<1	<100	7.17	4410	10.6
HP-1-20	13.3	<10	<100	7.1	760	11.7
HP-1-30	31.9	<1	<100			
HP-1-40	41.5	<1	<100	7.84	1700	13.4
HP-1-50	<1	<1	<1	7.69	770	13.9
HP-9-15	220	48.9	<100			
HP-9-25	392	<20	<1000			
HP-9-35	38.7	<4	<400	7.74	495	16.1
HP-9-45	6.8	<1	<100	7.43	904	16.4
HP-9-55	<1	<1	<100	7.57	1049	12.8

**Table 5-4. Comparison of Acetone, Chloroform, and  
Bromodichloromethane in Drilling Mud and  
Deep Monitor Well Groundwater Samples  
(Concentrations in  $\mu\text{g/l}$ )**

<b>Analyte</b>	<b>Drilling Mud</b>	<b>DW-1</b>	<b>BGDW-2</b>
Acetone	690	Undetected	160
Chloroform	270	60	19
Bromodichloromethane	52	4	Undetected

**Table 5-5. Groundwater Samples Exceeding VDEQ Standards**

Constituent	VDEQ Groundwater Standard	VDEQ Surface Water Standard				Samples Exceeding Standard	Sample Concentration
		Freshwater Aquatic Life		Human Health			
		Acute Toxicity	Chronic Toxicity	Public Water Supplies	All Other Surface Waters		
VOCs (µg/l)							
PCE	--	--	--	317	3519	SW-2-1 SW-2-2	4800 3700
TCE	--	--	--	2.7	807	HP-15-35 HP-11-35	1371 866
1,1,1-TCA	--	--	--	3100	--	N/A	--
1,2-DCA	--	--	--	3.8	990	NONE	--
1,2-DCE	--	--	--	--	--	N/A	--
1,1-DCA	--	--	--	--	--	N/A	--
Acetone	--	--	--	--	--	N/A	--
1,1-DCE	--	--	--	--	--	--	--
Carbon Tetrachloride	--	--	--	2.5	45	SW-1-1 SW-1-1 FD SW-1-2	120 72 84
Methylene Chloride	--	--	--	--	--	N/A	--
Chloroform	--	--	--	57	4700	NONE	--
Bromodichloro-methane	--	--	--	--	--	N/A	--
TPH mg/l	1	--	--	--	--	SW-1-2	1-5

Table 5-5. (Continued)

Constituent	VDEQ Groundwater Standard	VDEQ Surface Water Standard				Samples Exceeding Standard	Sample Concentration
		Freshwater Aquatic Life		Human Health			
		Acute Toxicity	Chronic Toxicity	Public Water Supplies	All Other Surface Waters		
IOCs (µg/l)							
Antimony	--					N/A	
Arsenic	50	360	190	50		SW-2-2 SW-5-2	171 337
Cadmium	0.4	$e^{(1.128[\ln(\text{hardness}) - 3.828])}$	$e^{(0.7852[\ln(\text{hardness}) - 3.490])}$	10		SW-2-2 SW-4-2 SW-5-2 GW-4-2 DW-2 FD (U)	281 206 1120 63 0.5
Chromium	60	16 <sup>2</sup>	11 <sup>2</sup>	170 <sup>2</sup>	3400 <sup>2</sup>	SW-2-2 SW-4-2 SW-5-2 GW-4-2	281 206 1120 63
Lead	50	$e^{(1.273[\ln(\text{hardness}) - 1.460])}$	$e^{(1.273[\ln(\text{hardness}) - 4.705])}$	50		SW-2-2 SW-4-4 SW-5-2	116 102 516
Mercury	0.05	2.4	0.012	0.144	0.146	SW-2-2 GW-4-2 SW-5 (F)	0.140 0.3
Zinc	50	$e^{(0.8473[\ln(\text{hardness}) + 0.8604])}$	$e^{(0.8473[\ln(\text{hardness}) + 0.7614])}$			SW-2-2 SW-4-2 SW-5-2 GW-4-2	354 416 1580 101

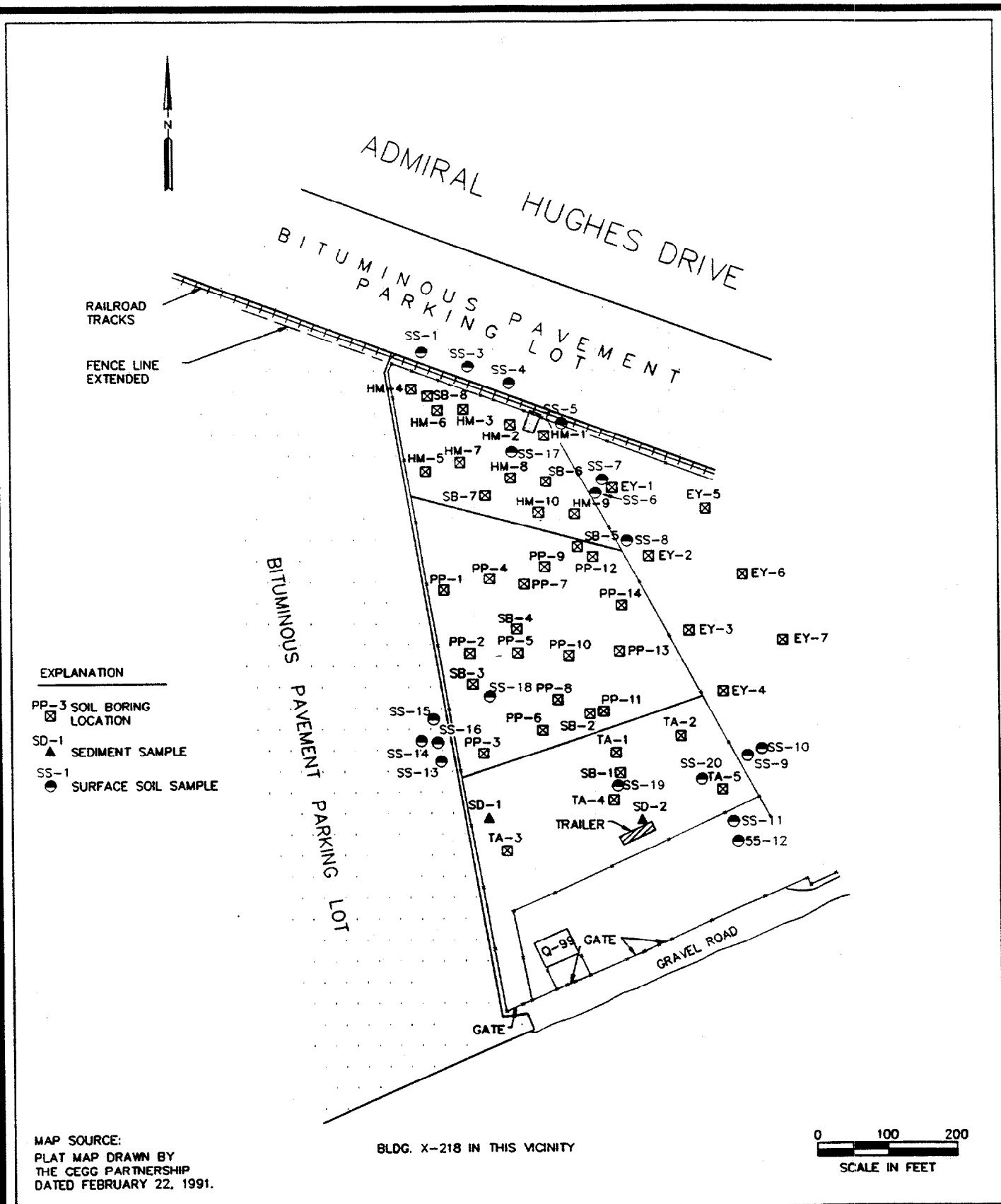
FD = Field Duplicate


U = Unfiltered

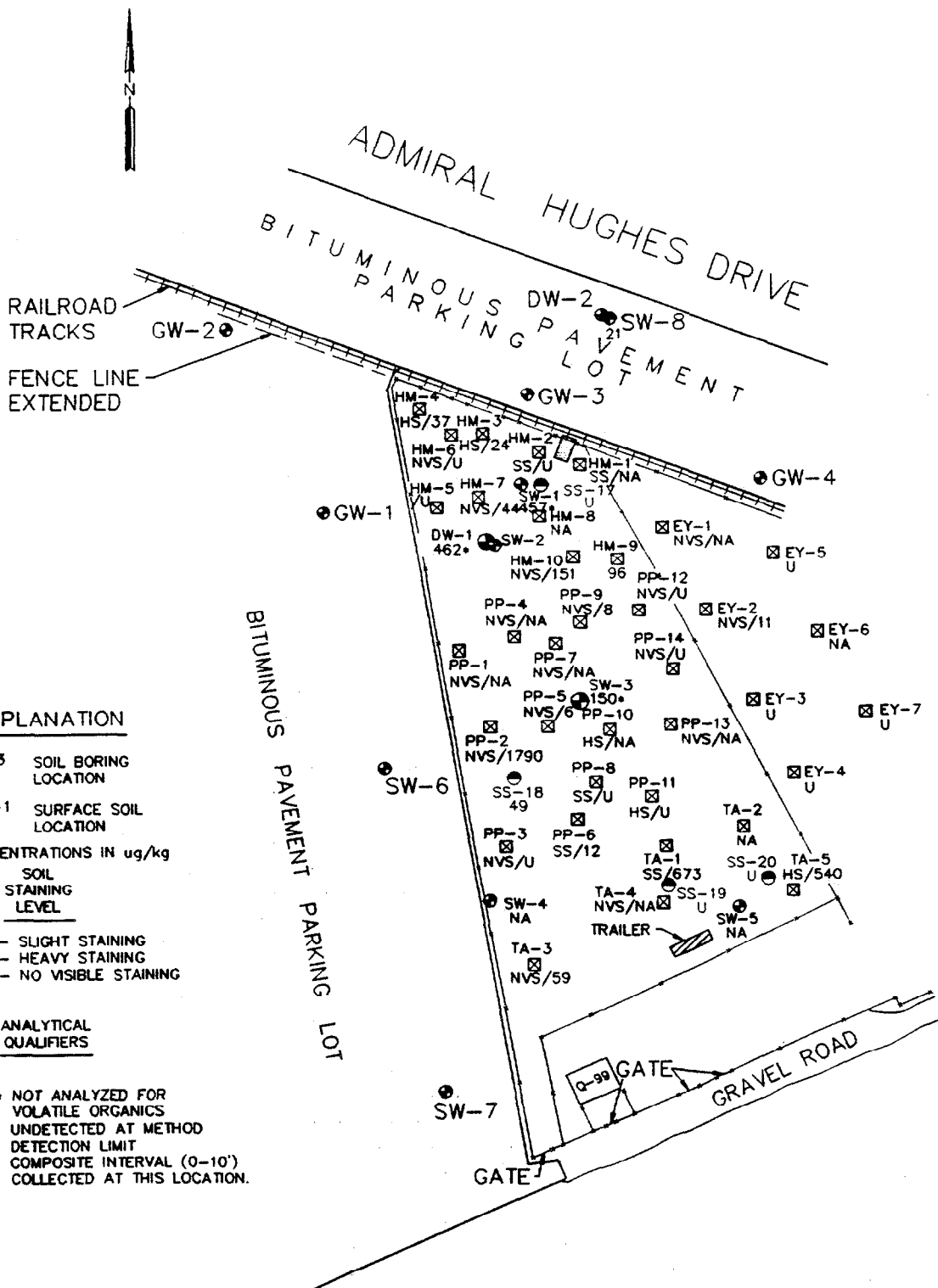
F = Filtered

<sup>1</sup>Drinking water and fish consumption<sup>2</sup>Fish consumption\*Hardness as calcium carbonate mg/e CaCO<sub>3</sub>

\*Chromium VI



	DATE	9-20-95	SCALE	SHOWN	TITLE SOIL AND SEDIMENT SAMPLE LOCATIONS Q AREA DRUM STORAGE YARD NORFOLK, VIRGINIA	
	DRAWN BY	JTG	APPROVED BY			
	JOB NO.	4921150	DWG. NO. / REV. NO.	SOIL150 / -	CLIENT	NAVFAC - Q AREA
					FIGURE	5-1



#### EXPLANATION

- PP-3 SOIL BORING LOCATION  
 SS-1 SURFACE SOIL LOCATION  
 CONCENTRATIONS IN ug/kg  
 SOIL STAINING LEVEL  
 SS - SLIGHT STAINING  
 HS - HEAVY STAINING  
 NVS - NO VISIBLE STAINING

#### ANALYTICAL QUALIFIERS

- NA - NOT ANALYZED FOR VOLATILE ORGANICS  
 U - UNDETECTED AT METHOD DETECTION LIMIT  
 \* - COMPOSITE INTERVAL (0-10') COLLECTED AT THIS LOCATION.

MAP SOURCE:  
 PLAT MAP DRAWN BY  
 THE CEGG PARTNERSHIP  
 DATED FEBRUARY 22, 1991.

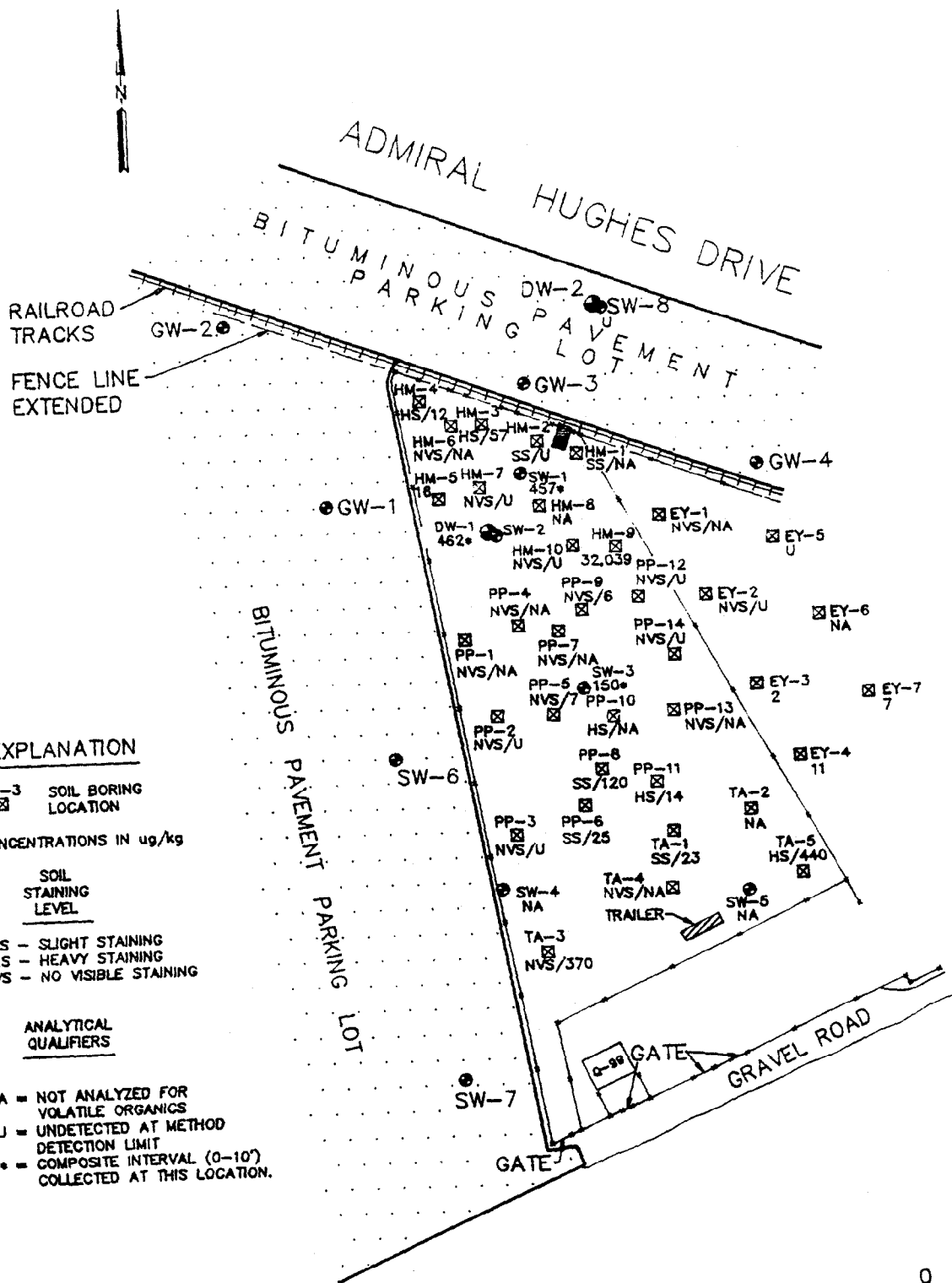
BLDG. X-218 IN THIS VICINITY

0 100 200  
 SCALE IN FEET



Environmental  
 Science &  
 Engineering

DATE 9-20-52	SCALE SHOWN	TITLE CONCENTRATIONS FOR TOTAL VOLATILE ORGA COMPOUNDS (EXCLUDING METHYLENE CHLORID IN SURFACE SOILS (0-18" INTERVAL) Q AREA DRUM STORAGE YARD, NORFOLK, VA	
DRAWN BY TJS	APPROVED BY		
JOB NO. 4921150	DWG. NO. / REV. NO. SOIL2 / 2	CLIENT NAVFAC - Q AREA	FIGURE 5-2



# EXPLANATION

PP-3 SOIL BORING LOCATION

CONCENTRATIONS IN ug/kg

## SOIL STAINING LEVEL

SS - SLIGHT STAINING  
HS - HEAVY STAINING  
NVS - NO VISIBLE STAINING

## ANALYTICAL QUALIFIERS

NA - NOT ANALYZED FOR VOLATILE ORGANICS  
U - UNDETECTED AT METHOD DETECTION LIMIT  
• - COMPOSITE INTERVAL (0-10') COLLECTED AT THIS LOCATION.

MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

BLDG. X-218 IN THIS VICINITY

0 100 200  
SCALE IN FEET



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Science &  
Engineering

DATE 4-4-91	SCALE SHOWN	TITLE CONCENTRATIONS FOR TOTAL VOLATILE ORGANIC COMPOUNDS (EXCLUDING METHYLENE CHLORIDE) IN SURFACE SOILS (18-36" INTERVAL) Q AREA DRUM STORAGE YARD, NORFOLK, VA	
DRAWN BY LAF	APPROVED BY		
JOB NO. 4901107	DWG. NO. / REV. NO. SOIL3 / -	CLIENT LANTNAVFACENGCOM	FIGURE 5-3

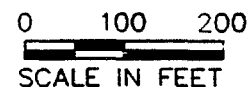
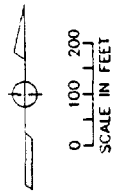


FIGURE 5-4

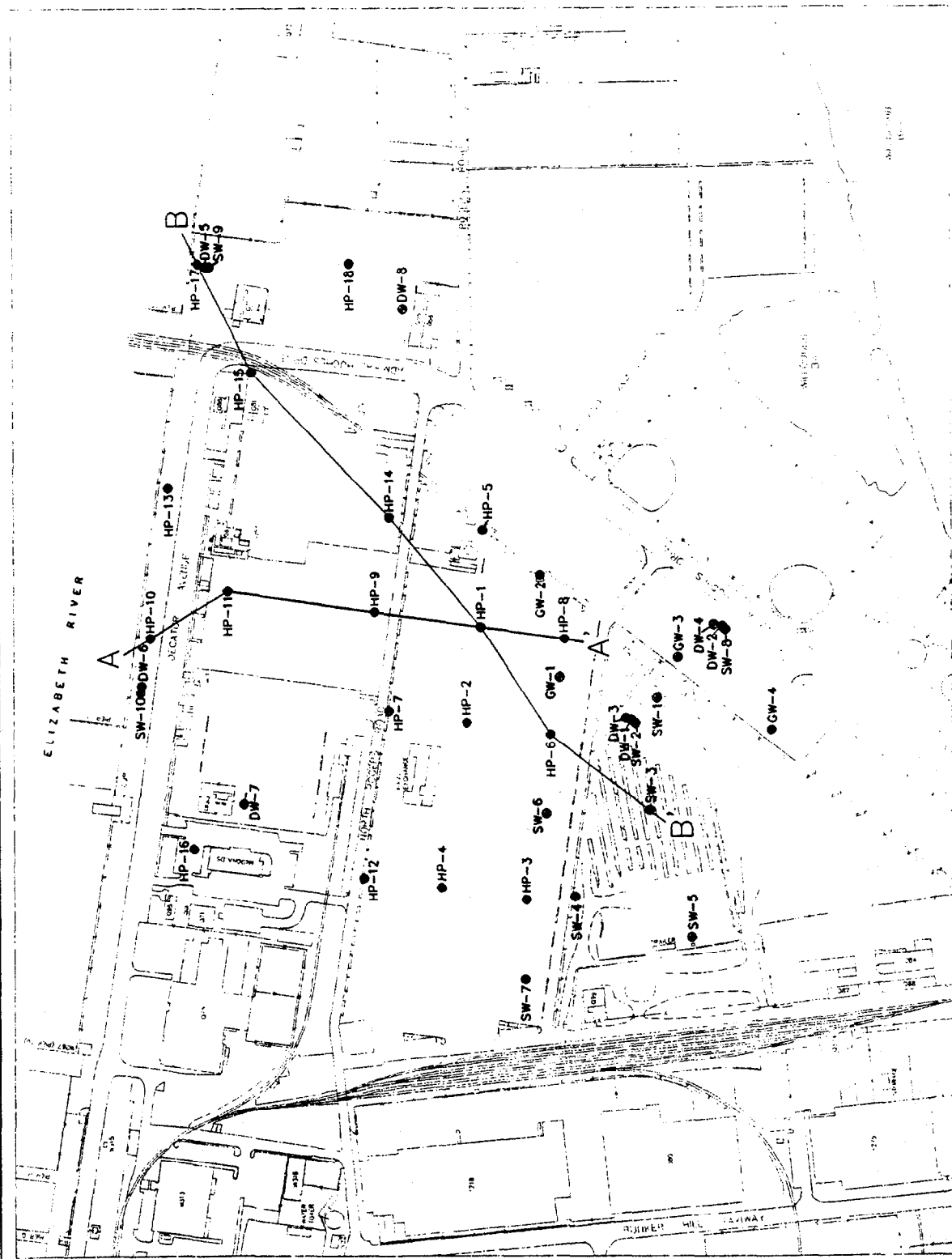






LEGEND

- HYDROPUNCH LOCATION
- MONITOR WELL LOCATION



Environmental  
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Engineering

MONITOR WELL, HYDROPUNCH AND TCE  
CONCENTRATION CROSS SECTION LOCATIONS  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

TITLE

SCALE  
SHOWN

DATE  
10-6-95

DRAWN BY  
TJF

APPROVED BY

CLIENT

DWG. NO. / REV. NO.

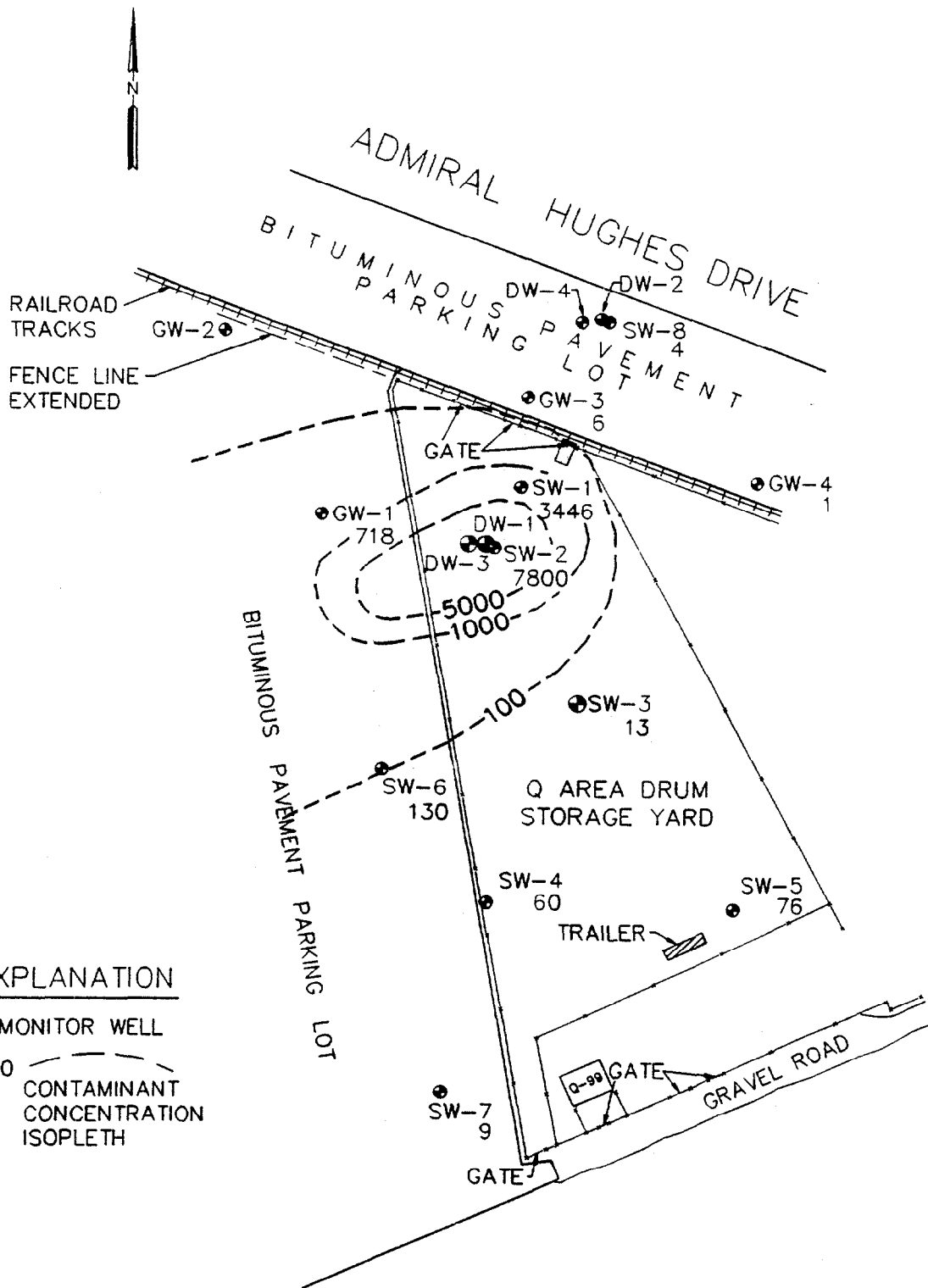
4921150

QDLA / -

NAVYFAC - Q AREA

FIGURE

5-6



### EXPLANATION

- MONITOR WELL
- 2.60 ———— CONTAMINANT CONCENTRATION ISOPLETH

MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

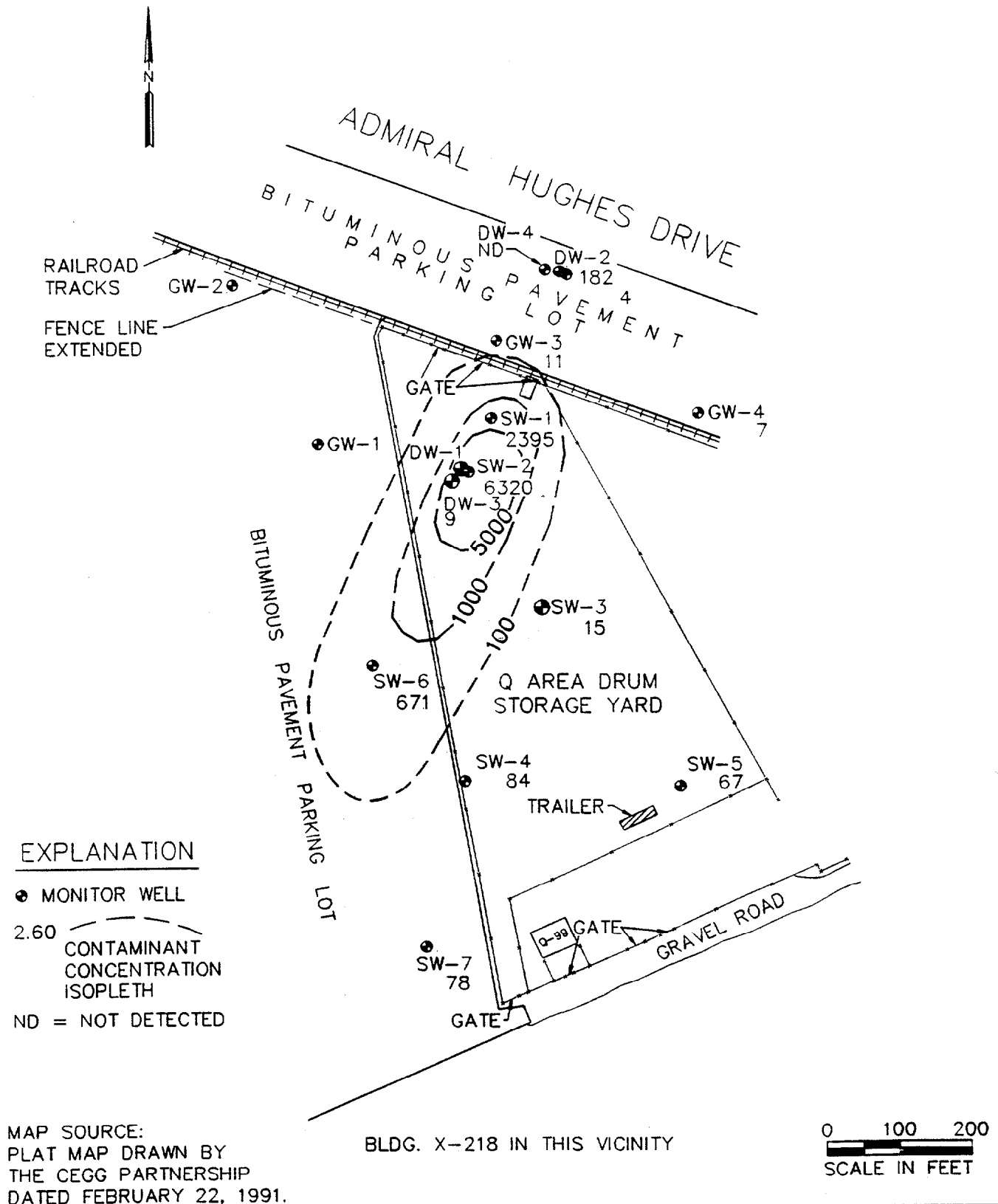
BLDG. X-218 IN THIS VICINITY

0 100 200  
SCALE IN FEET



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Engineering

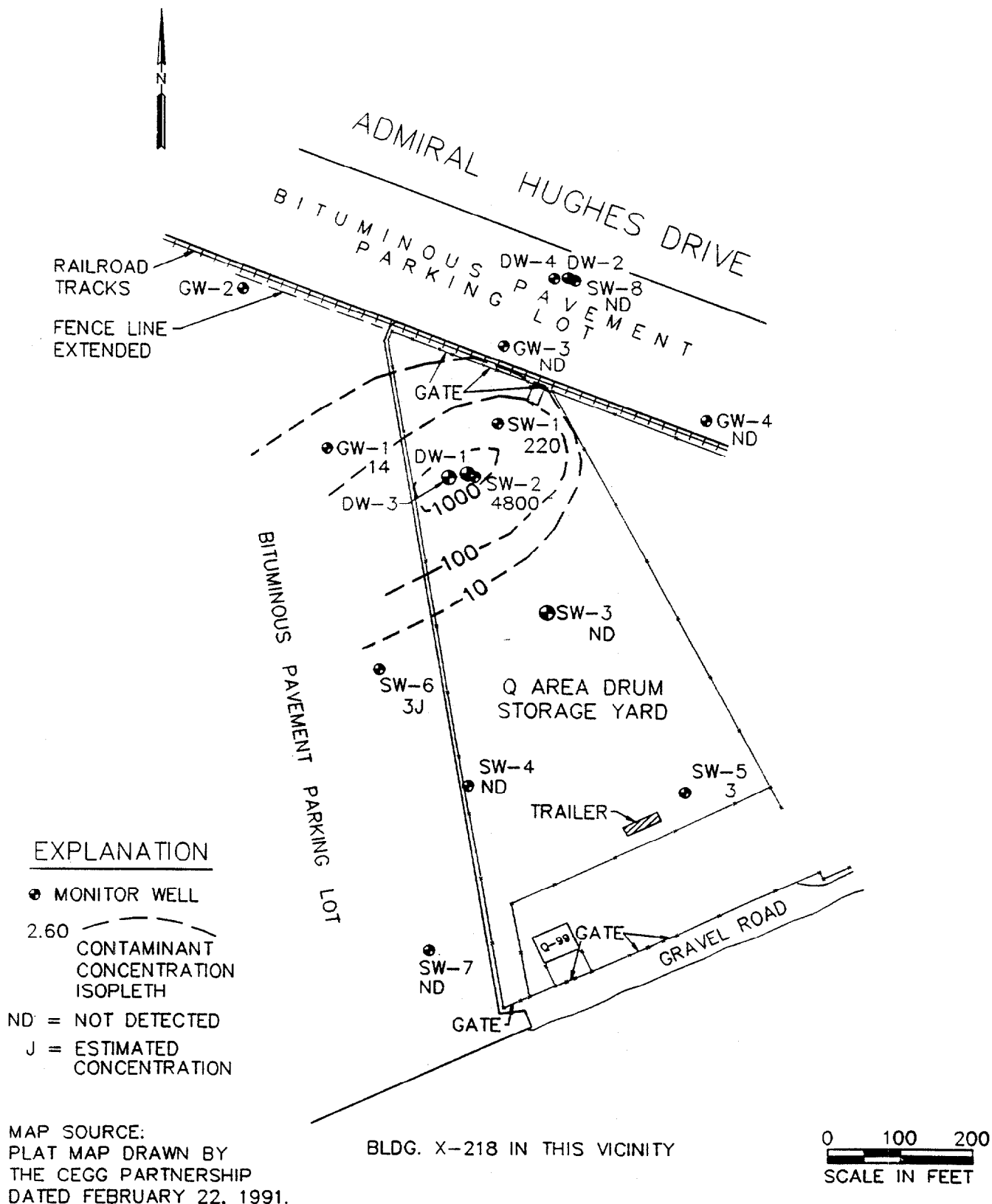
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DRAWN BY TJF	APPROVED BY		
JOB NO. 4921150	DWG. NO./ REV. NO. QB6A /	CLIENT LANTNAVFACENGCOM	FIGURE 5-7



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Engineering**

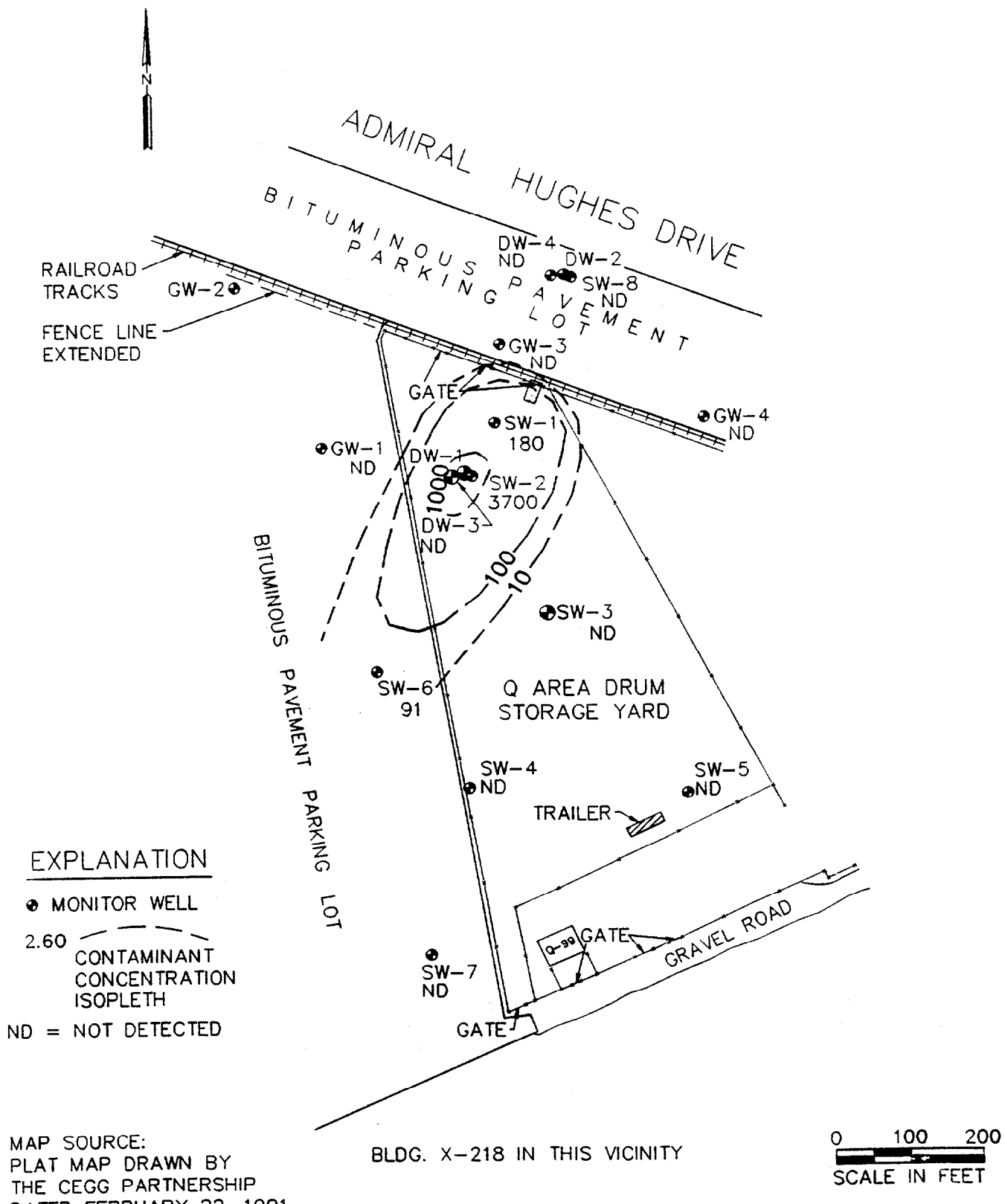
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DRAWN BY TJF	APPROVED BY
JOB NO. 4921150	DWG. NO./ REV. NO. QB7A /

TITLE ISOCONCENTRATION PLOT FOR TOTAL VOLATILE ORGANICS (EXCLUDING METHYLENE CHLORIDE) (UG/L) DEEP INTERVAL Q AREA DRUM STORAGE YARD, NORFOLK, VA	
CLIENT LANTNAVFACENGCOM	FIGURE 5-8



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DATE 10-6-95	SCALE SHOWN	TITLE ISOCONCENTRATION PLOT FOR PCE (UG/L) SHALLOW INTERVAL (10-15') Q AREA DRUM STORAGE YARD, NORFOLK, VA
DRAWN BY TJF	APPROVED BY	
JOB NO. 4921150	DWG. NO. / REV. NO. QB8A /	CLIENT LANTNAVFACENGCOM
		FIGURE 5-9



**EXPLANATION**

● MONITOR WELL

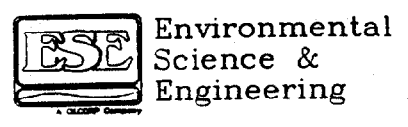
2.60  
CONTAMINANT  
CONCENTRATION  
ISOPLETH

ND = NOT DETECTED

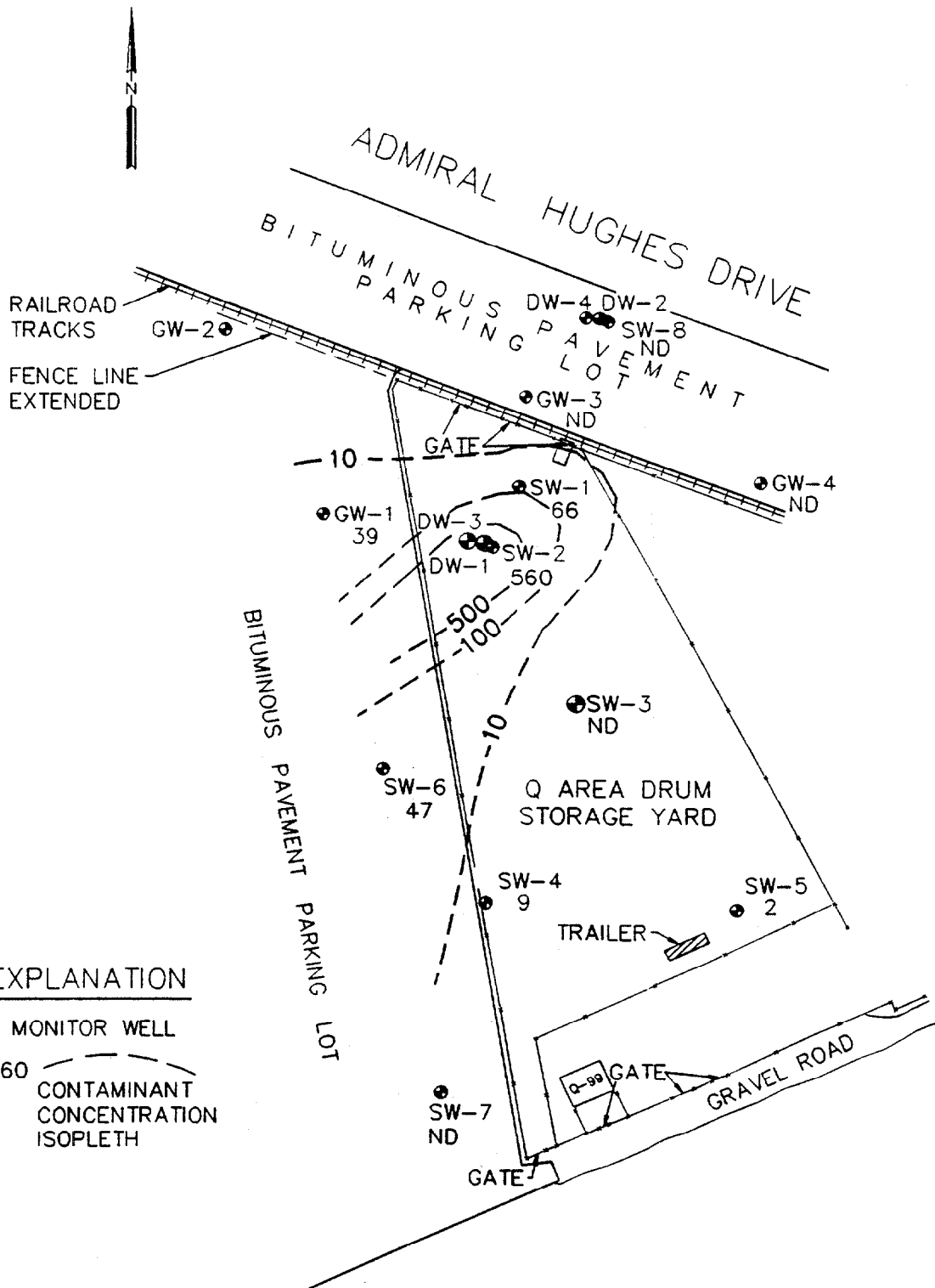
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THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

BLDG. X-218 IN THIS VICINITY

0 100 200  
SCALE IN FEET



DATE 10-6-95	SCALE SHOWN	TITLE ISOCONCENTRATION PLOT FOR PCE (UG/L) DEEP INTERVAL Q AREA DRUM STORAGE YARD, NORFOLK, VA
DRAWN BY TJF	APPROVED BY	
JOB NO. 4921150	DWG. NO. / REV. NO. QB9A /	CLIENT LANTNAVFACENGCOM
		FIGURE 5-10



# EXPLANATION

- MONITOR WELL
- 2.60 - - - - -  
CONTAMINANT  
CONCENTRATION  
ISOPLETH

MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

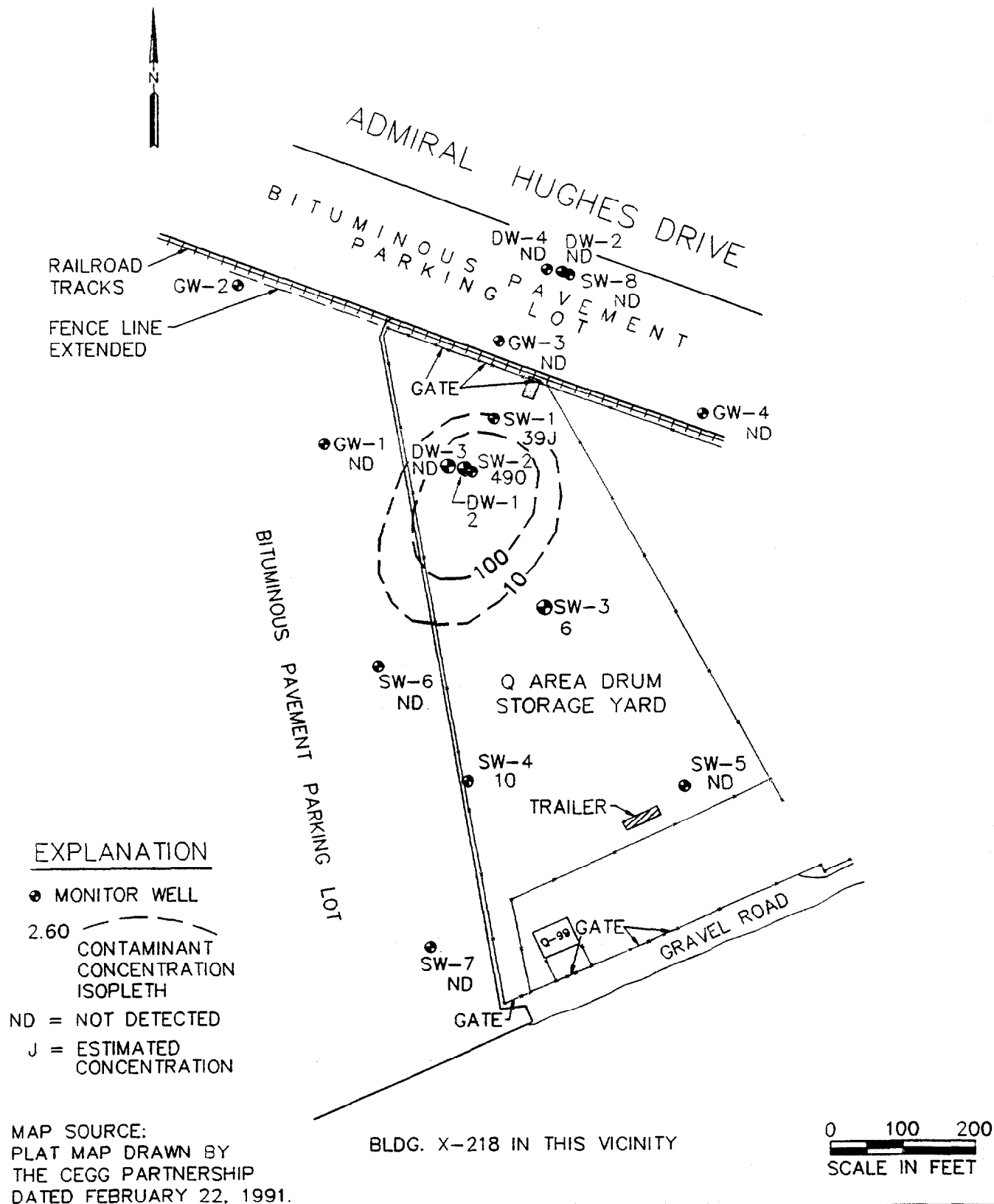
BLDG. X-218 IN THIS VICINITY

0 100 200  
SCALE IN FEET



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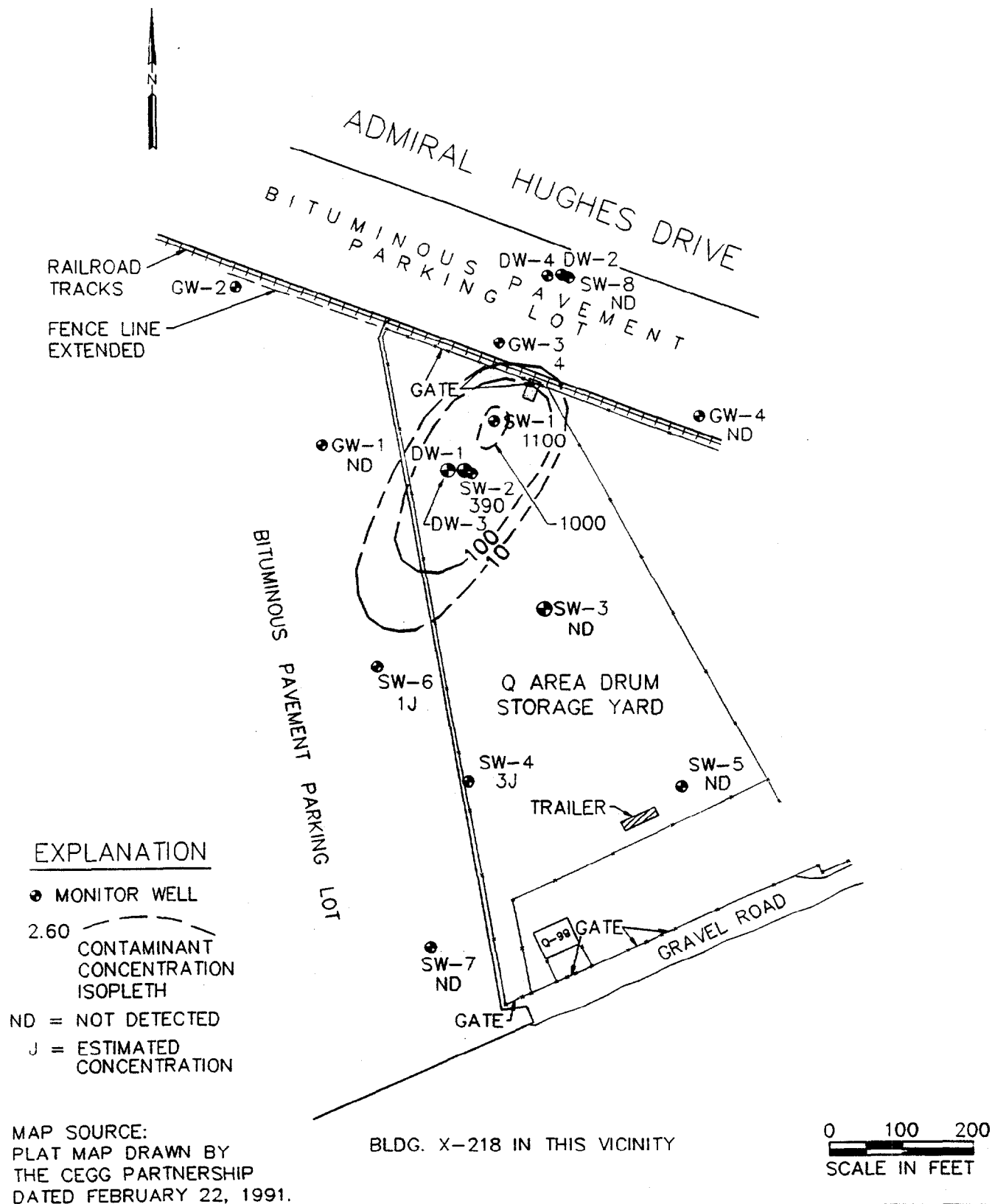
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DRAWN BY TJF	APPROVED BY	
JOB NO. 4921150	DWG. NO. / REV. NO. QB10A /	CLIENT LANTNAVFACENGCOM
		FIGURE 5-11



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Engineering**

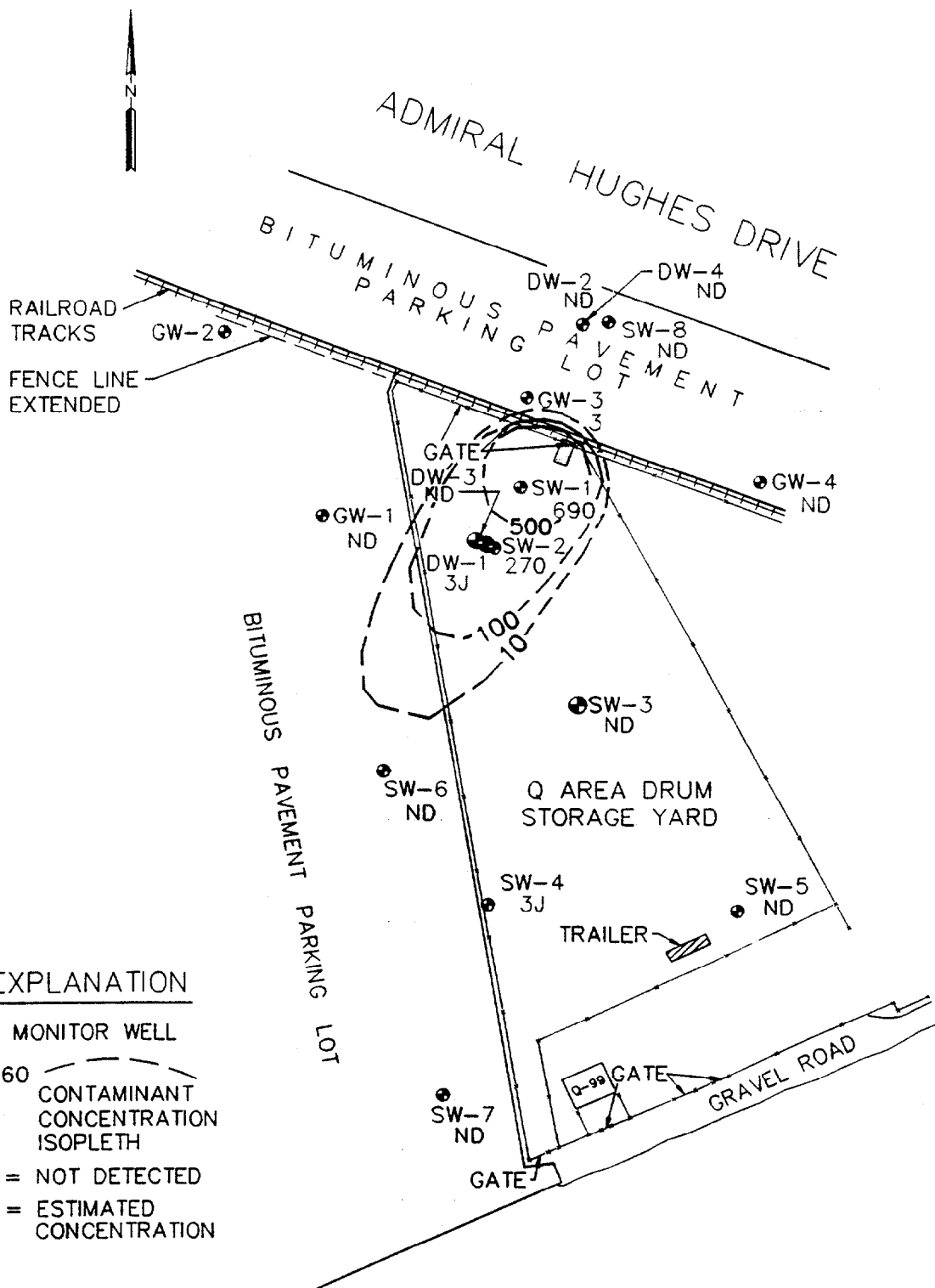
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DRAWN BY TJF	APPROVED BY		
JOB NO. 4921150	DWG. NO./ REV. NO. QB11A /	CLIENT LANTNAVFACENGCOM	FIGURE 5-12





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Engineering

DATE 10-5-95	SCALE SHOWN	TITLE ISOCONCENTRATION PLOT FOR 1,1,1 TCA (UG/L) SHALLOW INTERVAL (10-15') Q AREA DRUM STORAGE YARD, NORFOLK, VA
DRAWN BY TJF	APPROVED BY	
JOB NO. 4921150	DWG. NO./ REV. NO. QB12A /	CLIENT LANTNAVFACENGCOM
		FIGURE 5-13



# EXPLANATION

● MONITOR WELL

2.60  
CONTAMINANT  
CONCENTRATION  
ISOPLETH

ND = NOT DETECTED

J = ESTIMATED  
CONCENTRATION

MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

BLDG. X-218 IN THIS VICINITY

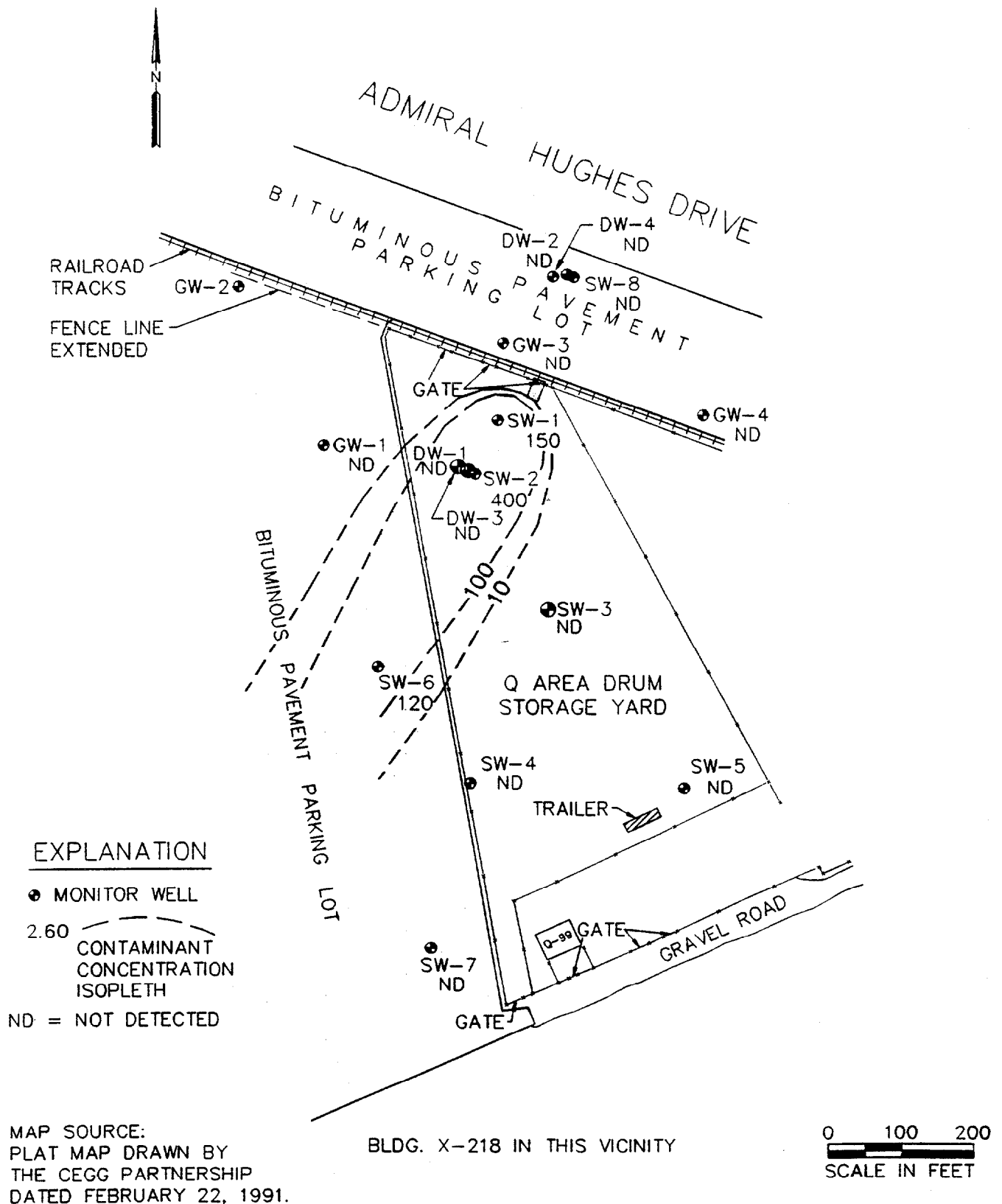
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SCALE IN FEET



Environmental  
Science &  
Engineering

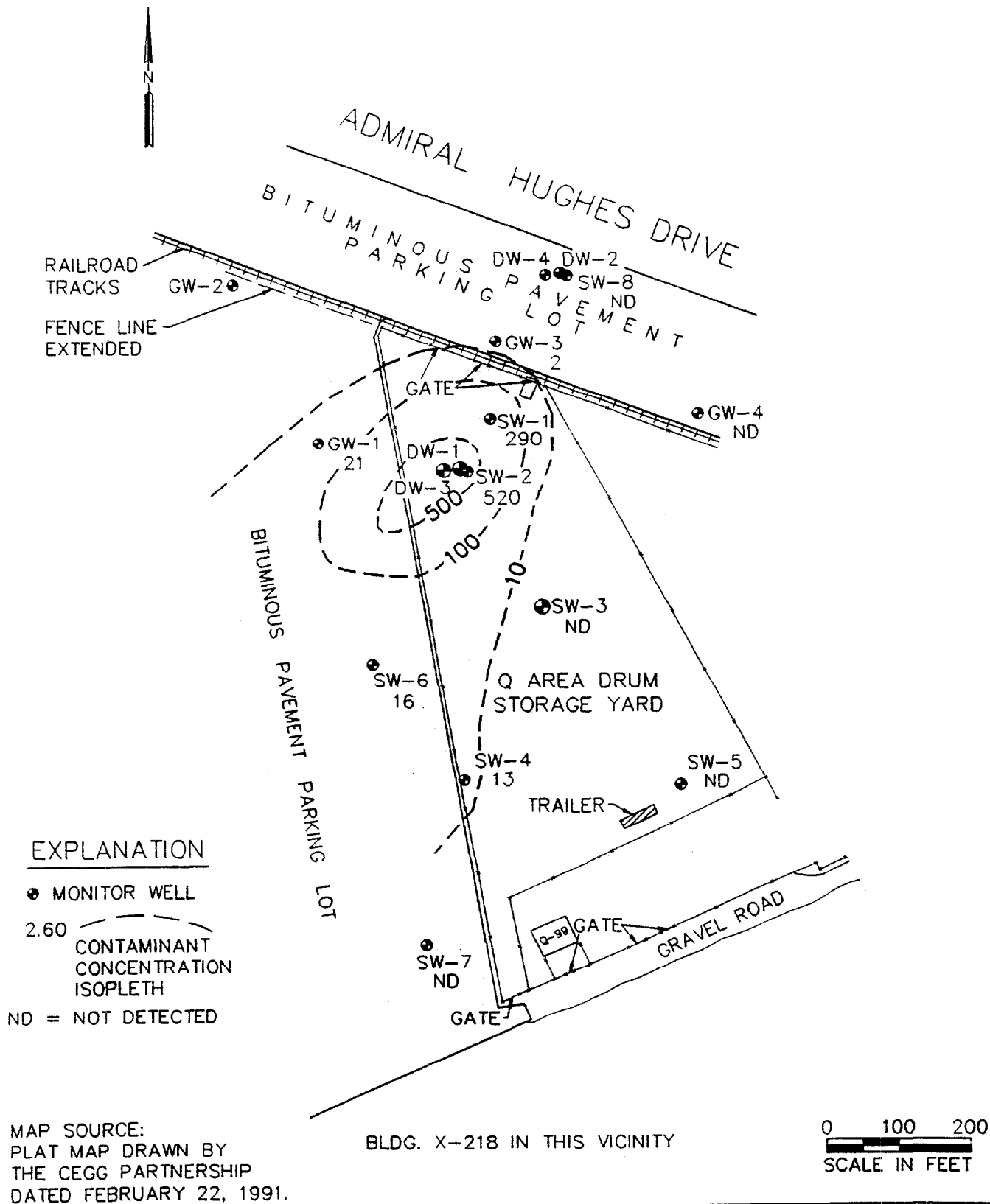
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DRAWN BY TJF	APPROVED BY		
JOB NO. 4921150	DWG. NO. / REV. NO. QB13A / -	CLIENT LANTNAVFACENGCOM	FIGURE 5-14





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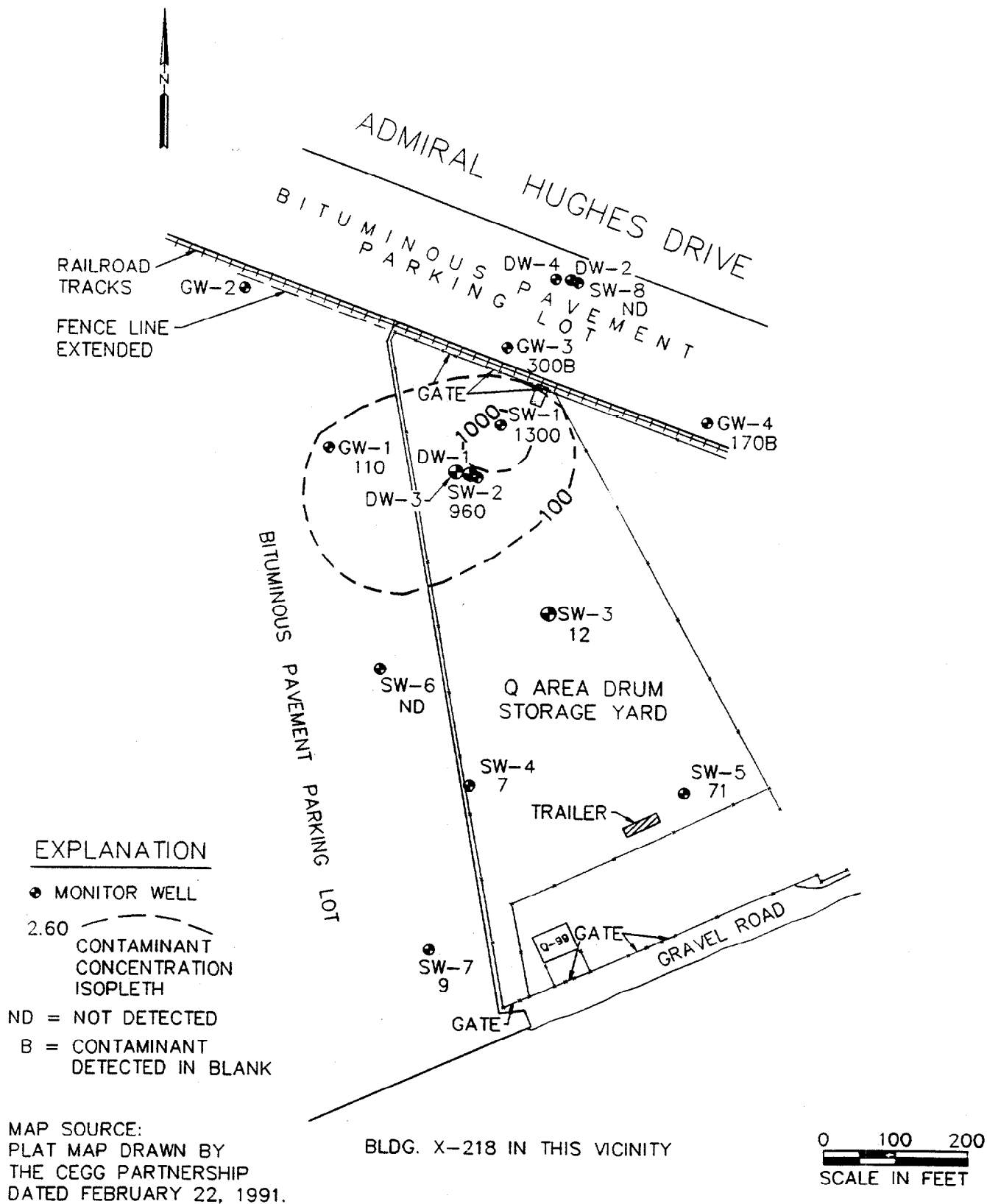
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DRAWN BY TJF	APPROVED BY	
JOB NO. 4921150	DWG. NO./ REV. NO. QB15A /	CLIENT LANTNAVFACENGCOM
		FIGURE 5-16



**Environmental  
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Engineering**

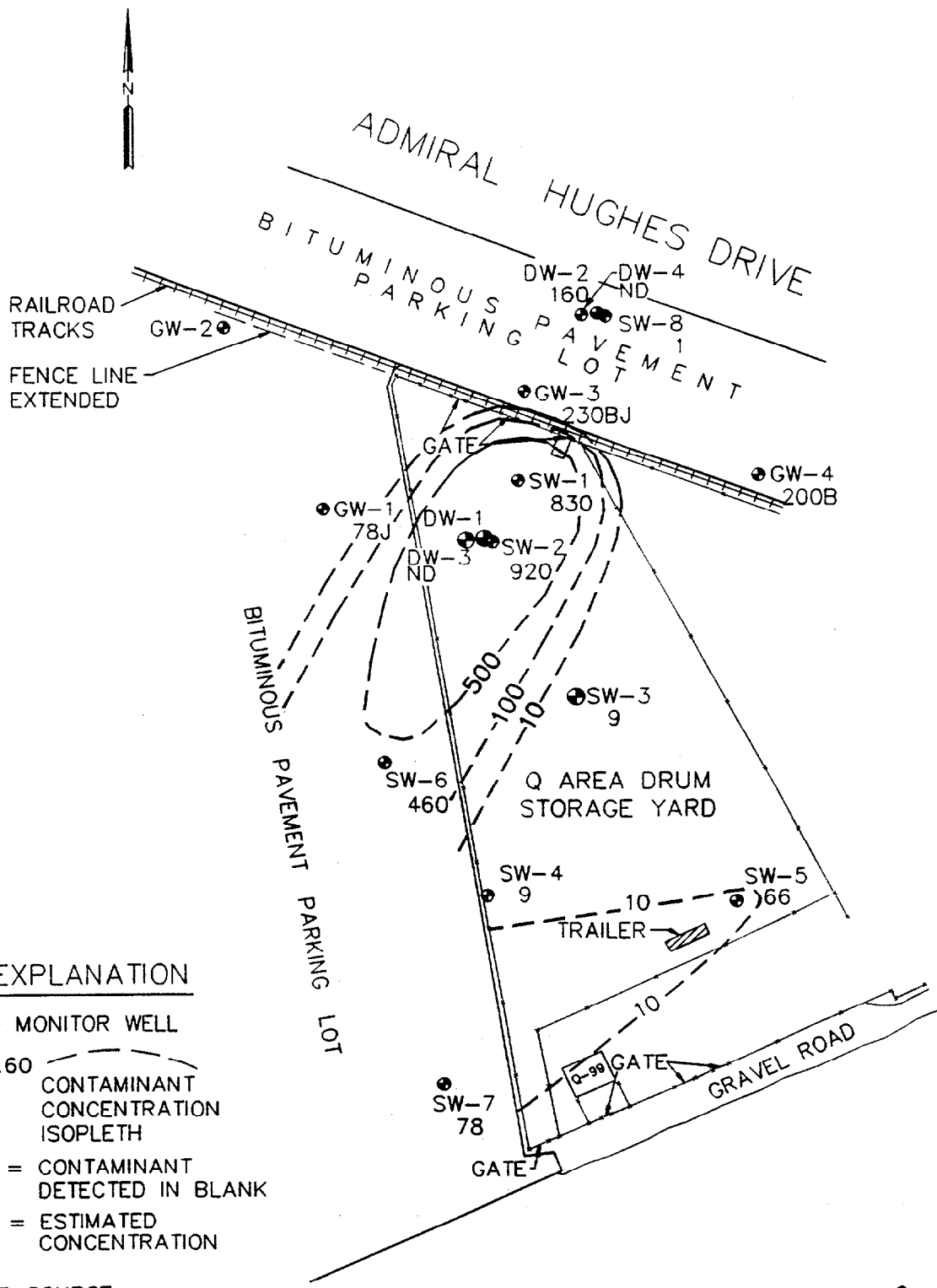
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DRAWN BY TJF	APPROVED BY		
JOB NO. 4921150	DWG. NO./ REV. NO. QB16A /	CLIENT LANTNAVFACENGCOM	FIGURE 5-17





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DATE 10-6-95	SCALE SHOWN	TITLE ISOCONCENTRATION PLOT FOR ACETONE (UG/L) SHALLOW INTERVALS (10-15') Q AREA DRUM STORAGE YARD, NORFOLK, VA
DRAWN BY TJF	APPROVED BY	
JOB NO. 4921150	DWG. NO./ REV. NO. QB18A /	CLIENT LANTNAVFACENGCOM
		FIGURE 5-19

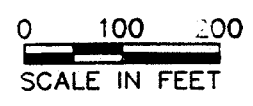


### EXPLANATION

- MONITOR WELL
- 2.60  
- - - - -  
CONTAMINANT  
CONCENTRATION  
ISOPLETH
- B = CONTAMINANT  
DETECTED IN BLANK
- J = ESTIMATED  
CONCENTRATION

MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

BLDG. X-218 IN THIS VICINITY

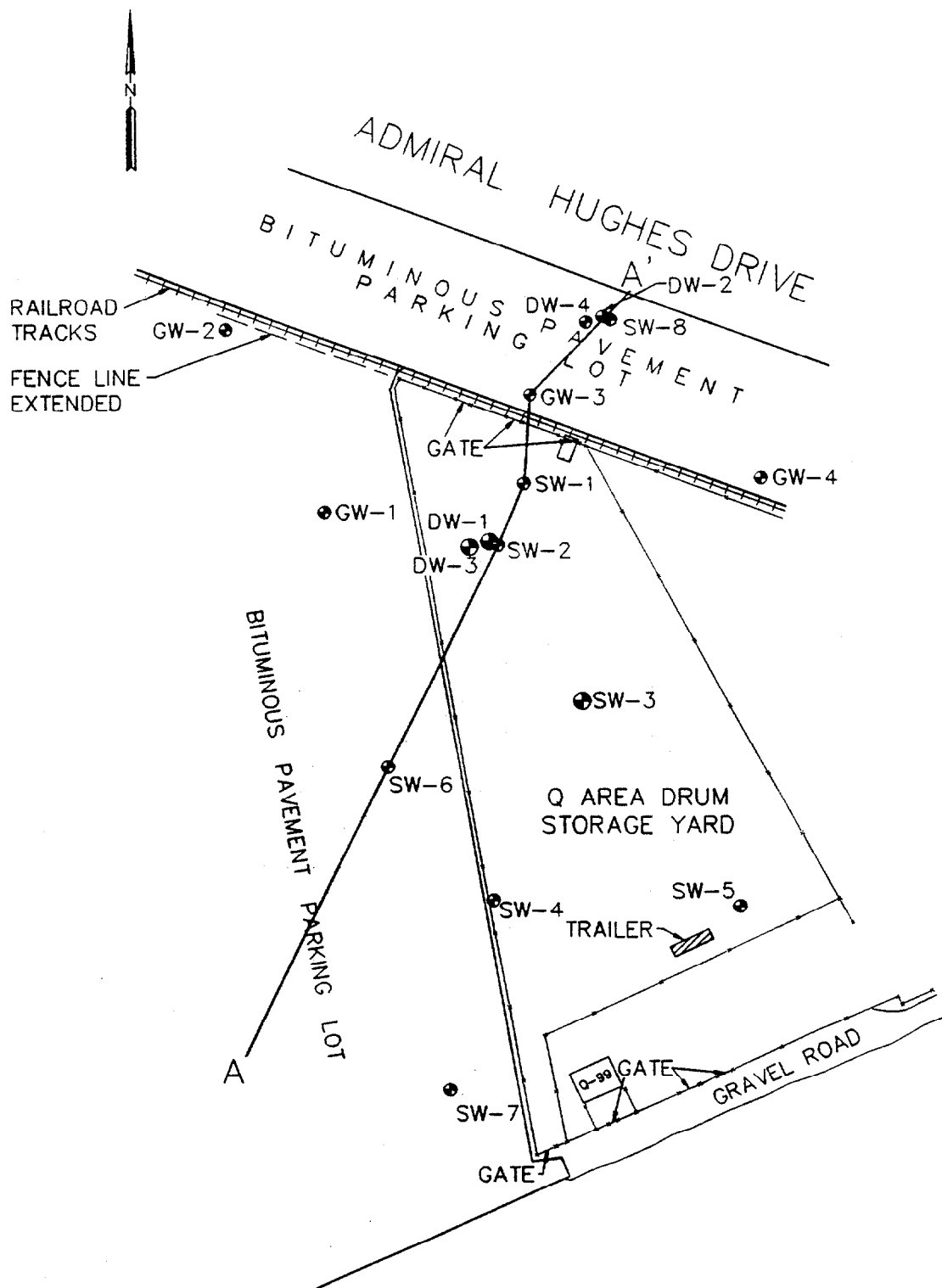


**Environmental  
Science &  
Engineering**

DATE 10-9-95	SCALE SHOWN	TITLE ISOCONCENTRATION PLOT FOR ACETONE (UG DEEP INTERVALS Q AREA DRUM STORAGE YARD, NORFOLK, VA	
DRAWN BY TJF	APPROVED BY		
JOB NO. 4921150	DWG. NO. / REV. NO. QB19A /	CLIENT LANTNAVFACENGCOM	FIGURE 5-20

DIS: 12-1107 FILE NAME: J4921150.DWG BY: USER: DATE: 1995-10-09





MAP SOURCE:  
PLAT MAP DRAWN BY  
THE CEGG PARTNERSHIP  
DATED FEBRUARY 22, 1991.

BLDG. X-218 IN THIS VICINITY

0 100 200  
SCALE IN FEET



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Science &  
Engineering

DATE  
10-11-95

DRAWN BY  
TJF

JOB NO.  
4921150

SCALE  
SHOWN

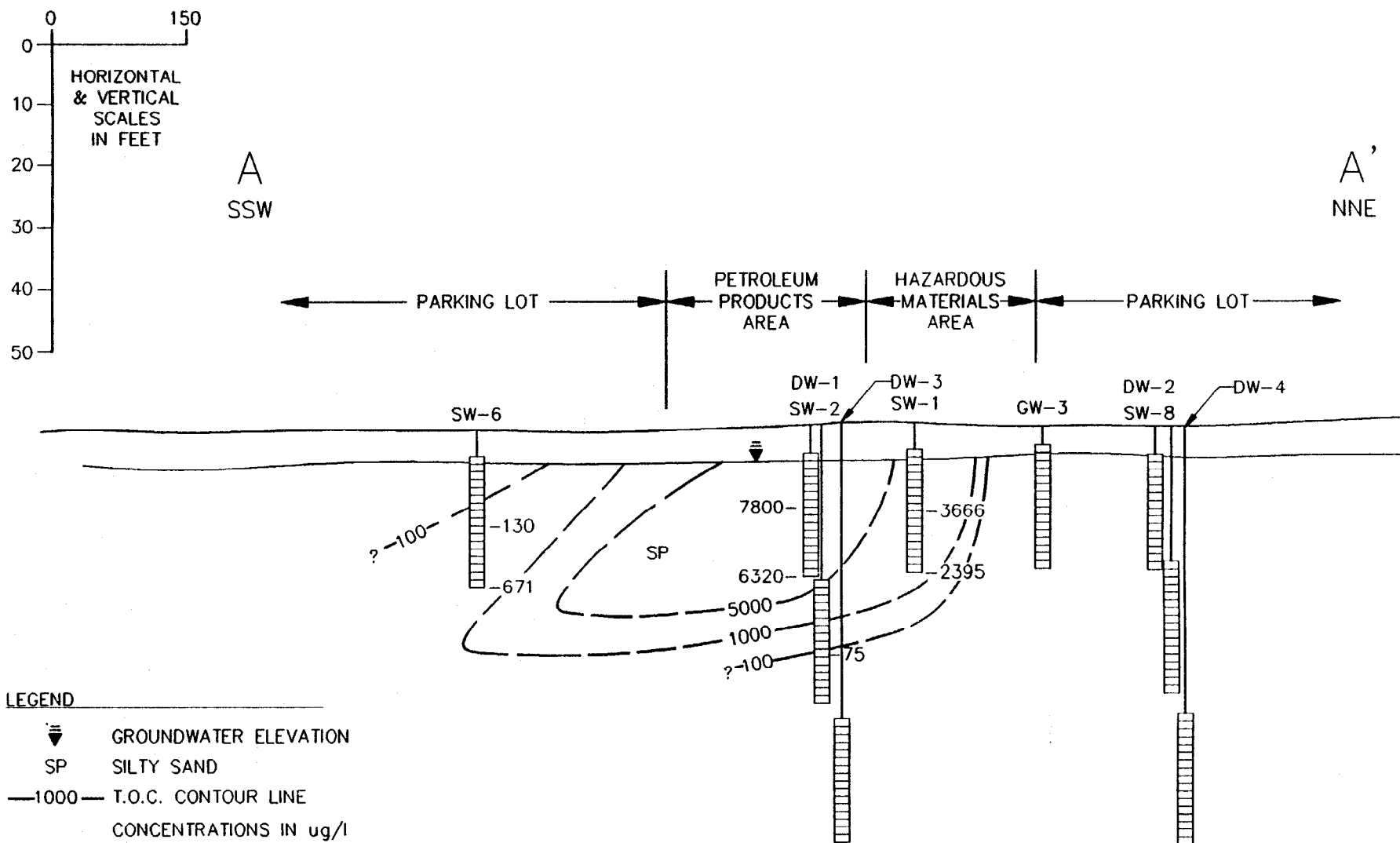
APPROVED BY

DWG. NO. / REV. NO.  
QXSECA /

TITLE  
LINE OF SECTION FOR FIGURES  
4-21 THROUGH 4-26  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
LANTNAVFACENGCOM

FIGURE  
5-21



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Engineering

DATE  
10-11-95

DRAWN BY  
TJF

JOB NO.  
4921150

SCALE  
SHOWN

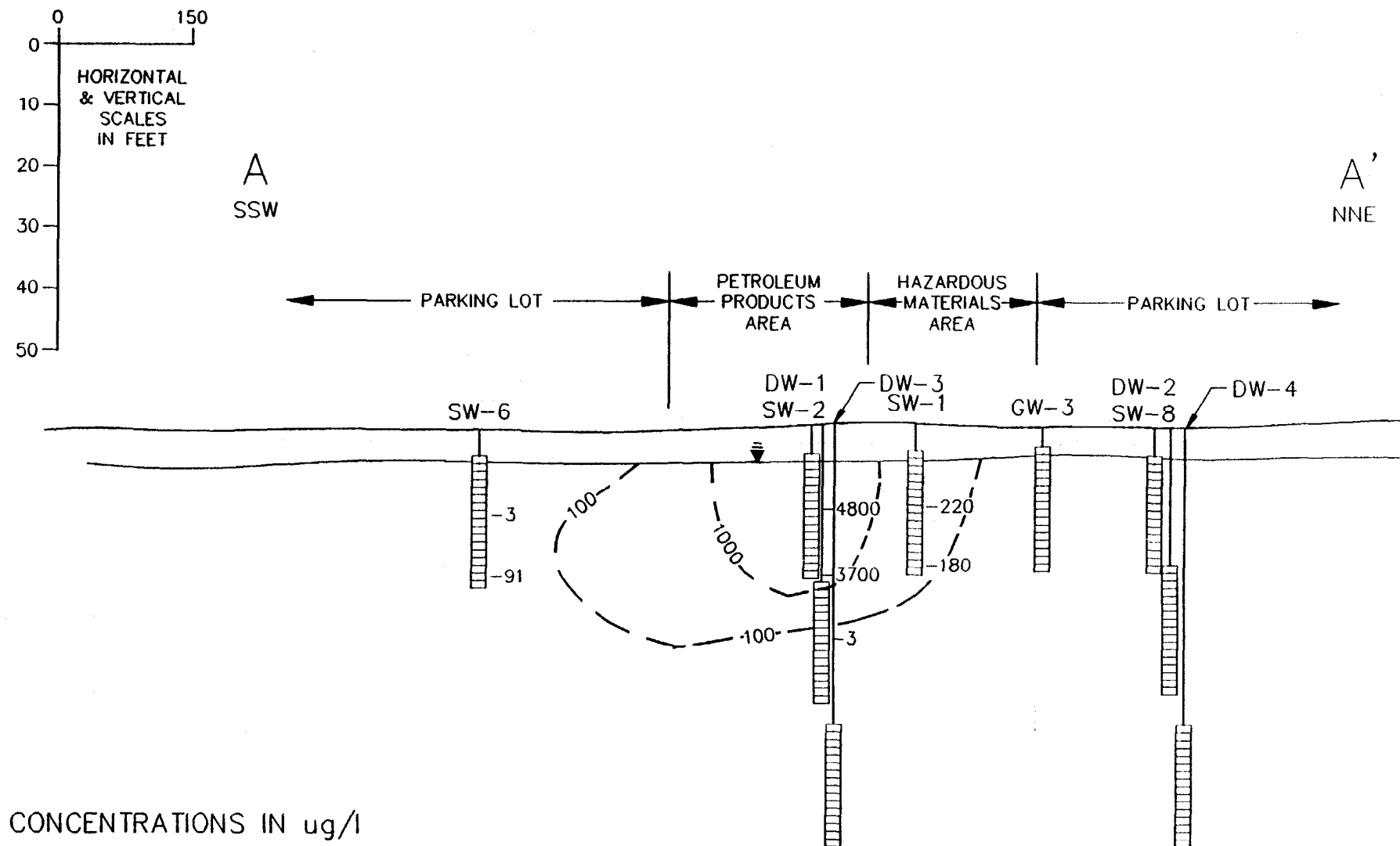
APPROVED BY

DWG. NO./ REV. NO  
QONEA /

TITLE  
CONTAINMENT PLUME, VERTICAL CONFIGURATION,  
TOTAL VOLATILE ORGANICS  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
LANNAVFACENGCOM

FIGURE  
5-22



Environmental  
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Engineering

DATE  
10-11-95

DRAWN BY  
TJF

JOB NO.  
4921150

SCALE  
SHOWN

APPROVED BY

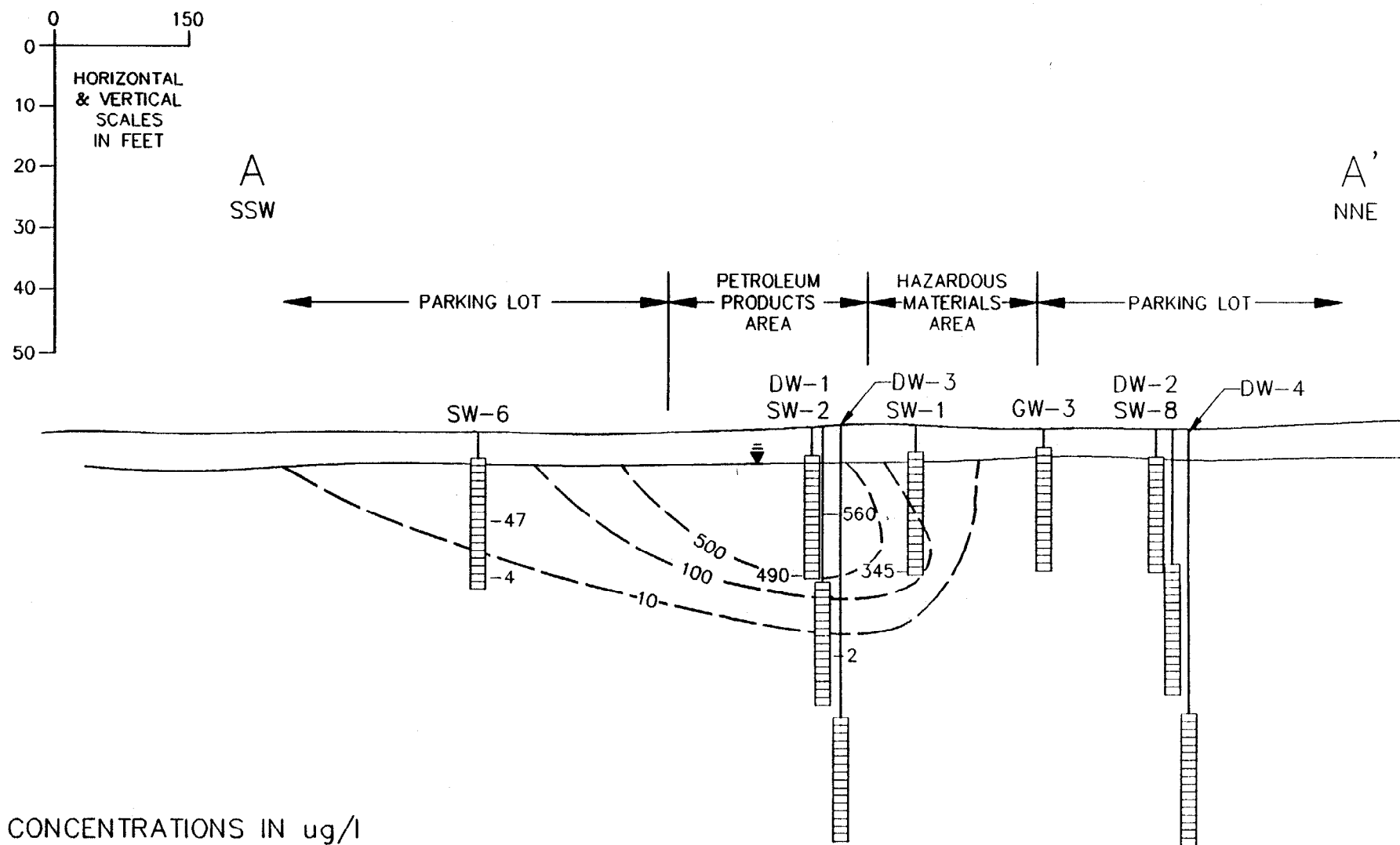
DWG. NO. / REV. NO.  
QTWOA /

TITLE  
CONTAMINANT PLUME, VERTICAL CONFIGURATION,  
PCE (TETRACHLOROETHENE)  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
LANTNAVFACENGCOM

FIGURE  
5-23

DR: K-490107, FILE NAME: JN4901070THREEA, BY: USER, DATE: 1995-10-11



Environmental  
Science &  
Engineering

DATE  
10-11-95

DRAWN BY  
TJF

JOB NO.  
4921150

SCALE  
SHOWN

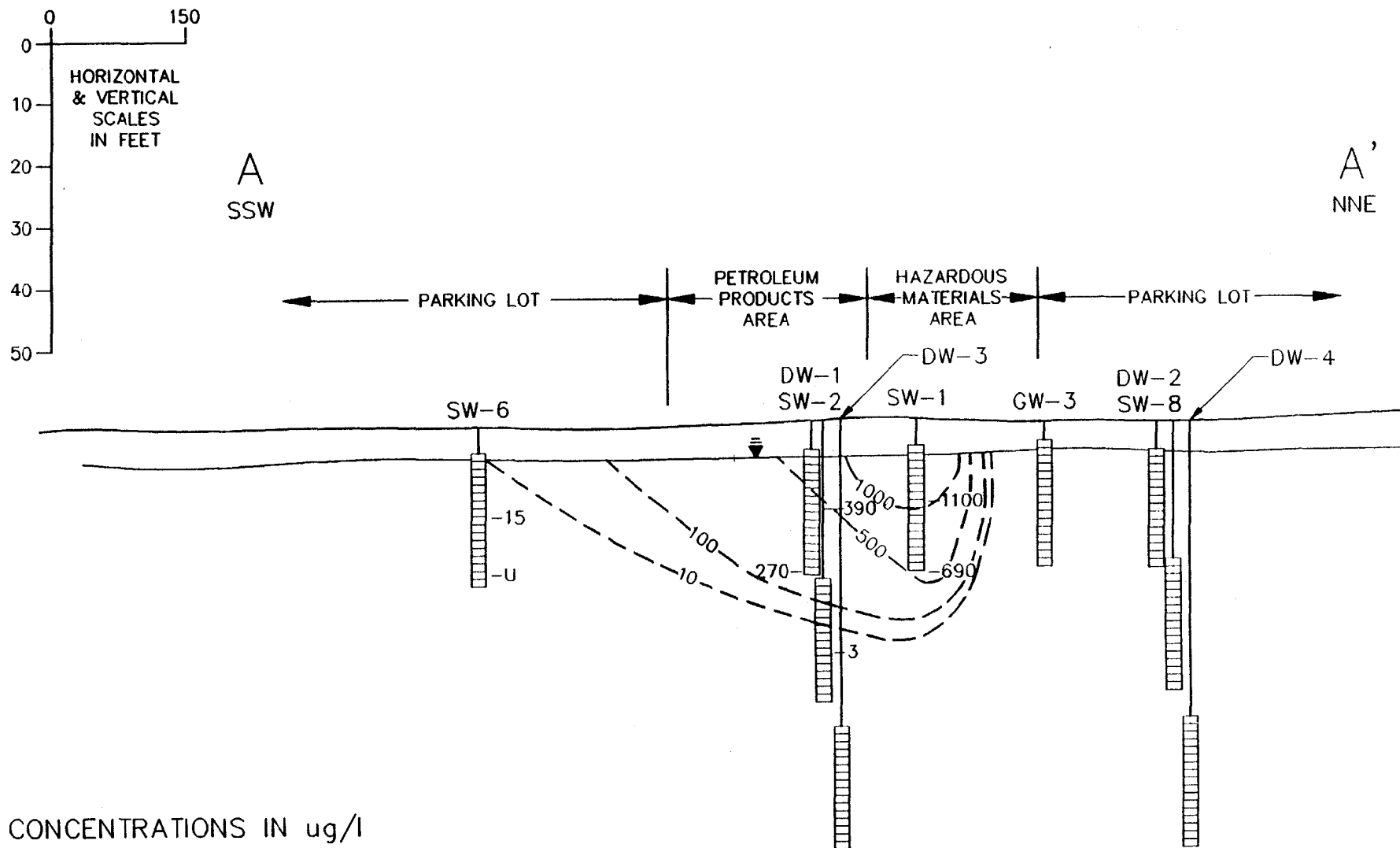
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DWG. NO. / REV. NO.  
QTHREEA /

TITLE  
CONTAMINANT PLUME, VERTICAL CONFIGURATION,  
TCE (TRICHLOROETHENE)  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
LANNAVFACENGCOM

FIGURE  
5-24



Environmental  
Science &  
Engineering

DATE  
10-11-95

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TJF

JOB NO.  
4921150

SCALE  
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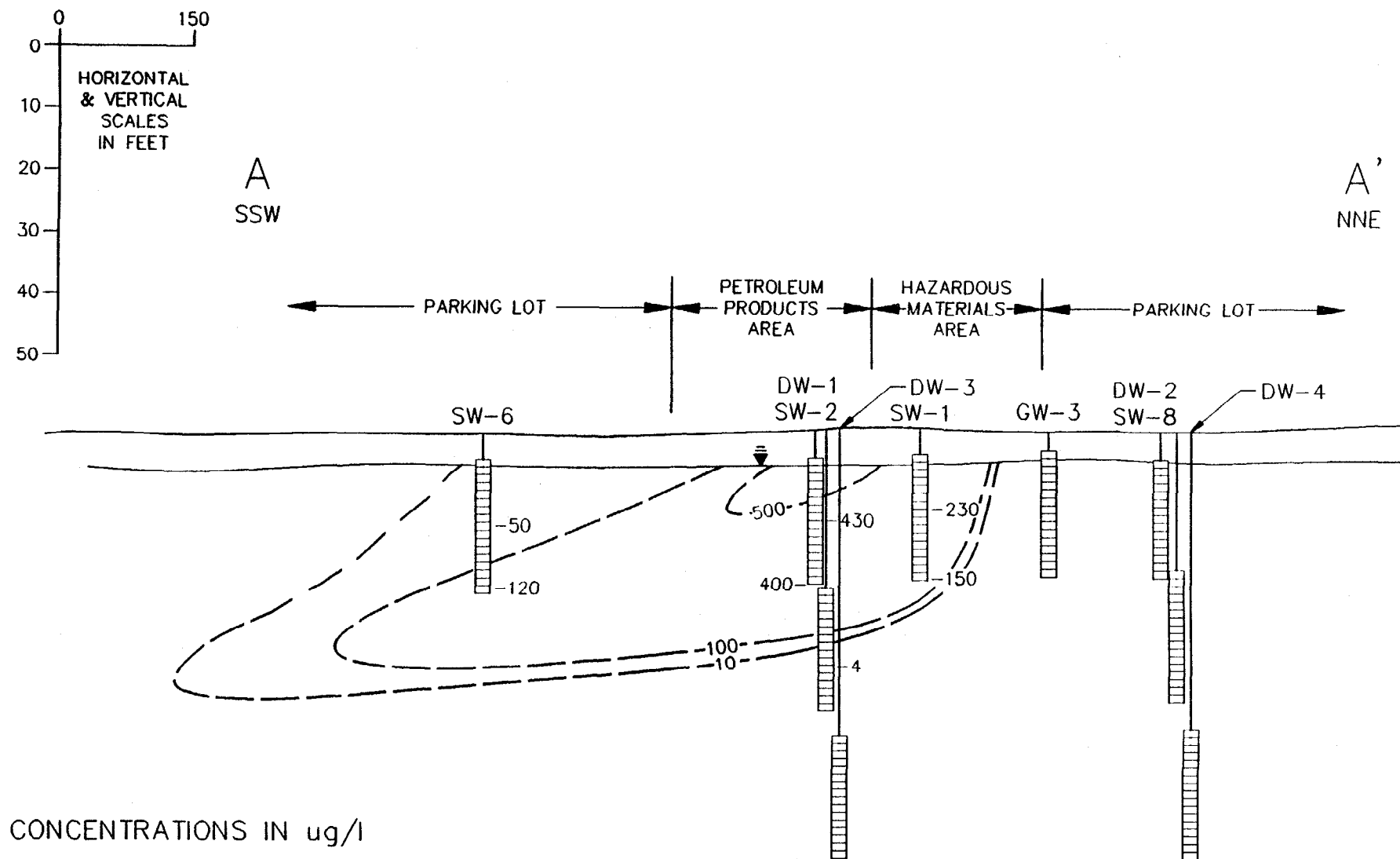
APPROVED BY

DWG. NO. / REV. NO.  
QFOURA /

TITLE  
CONTAMINANT PLUME, VERTICAL CONFIGURATION, 1,1,1, -  
TRICHLOROETHANE (TCA)  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
LANTNAVFACENGCOM

FIGURE 5-25



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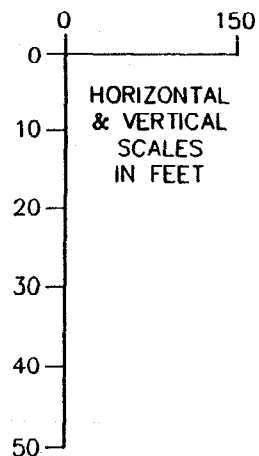
APPROVED BY

DWG. NO./REV. NO.  
QFIVEA /

TITLE  
CONTAMINANT PLUME, VERTICAL CONFIGURATION, 1,2 -  
DICHLOROETHENE (DCE)  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
LANTNAVFACENGCOM

FIGURE  
5-26



A  
SSW

A'  
NNE

PARKING LOT

PETROLEUM  
PRODUCTS  
AREA

HAZARDOUS  
MATERIALS  
AREA

PARKING LOT

SW-6

DW-1  
SW-2

DW-3  
SW-1

GW-3

DW-2  
SW-8

DW-4

-16

-U

500

-100

-10

520

540

-3

9

-290

-210

CONCENTRATIONS IN ug/l



Environmental  
Science &  
Engineering

DATE  
10-11-95

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TJF

JOB NO.  
4921150

SCALE  
SHOWN

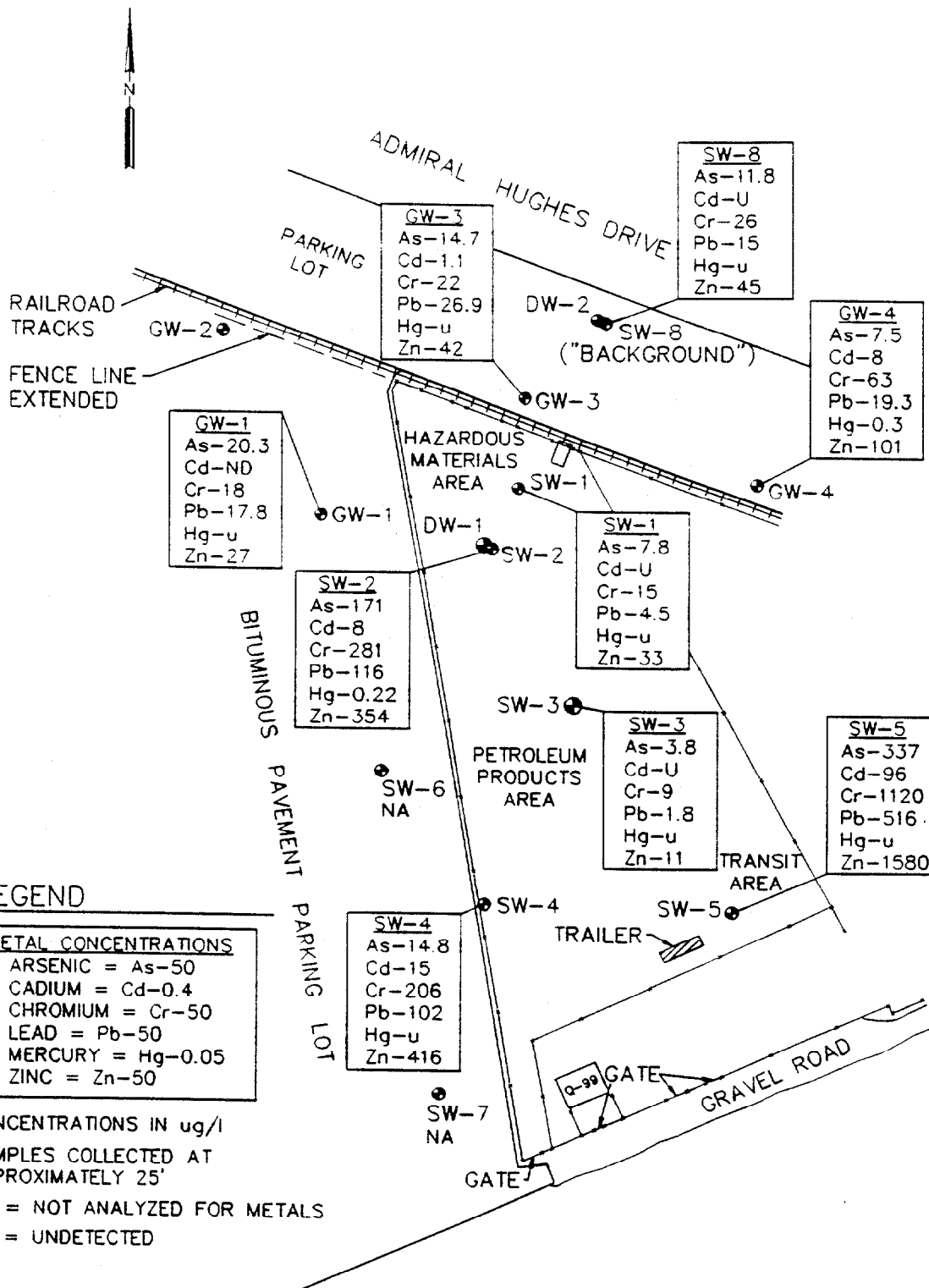
APPROVED BY

DWG. NO./ REV. NO  
QSIXA /

TITLE  
CONTAMINANT PLUME, VERTICAL CONFIGURATION, 1,1 -  
DICHLOROETHANE (DCA)  
Q AREA DRUM STORAGE YARD  
NORFOLK, VIRGINIA

CLIENT  
LANTNAVFACENGCOM

FIGURE  
5-27



MAP SOURCE:  
 PLAT MAP DRAWN BY  
 THE CEGG PARTNERSHIP  
 DATED FEBRUARY 22, 1991.

BLDG. X-218 IN THIS VICINITY

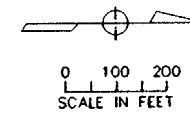
0 100 200  
 SCALE IN FEET



Environmental  
 Science &  
 Engineering

DATE 3-7-94	SCALE SHOWN	TITLE RESULTS OF PRIORITY POLLUTANT METALS ANALYSIS IN GROUNDWATER SAMPLES Q AREA DRUM STORAGE YARD NORFOLK, VIRGINIA	
DRAWN BY LAL	APPROVED BY		
JOB NO. 4921150	DWG. NO. / REV. NO. QUGLA / -	CLIENT NAVFAC - Q AREA	FIGURE 5-28





- HYDROPUNCH LOCATION
- MONITOR WELL LOCATION
- 27 PCE CONCENTRATION ( $\mu\text{g/l}$ )
- PCE CONTOUR LINE
- BDL BELOW DETECTION LIMITS

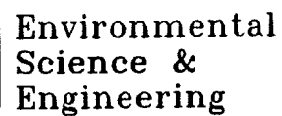
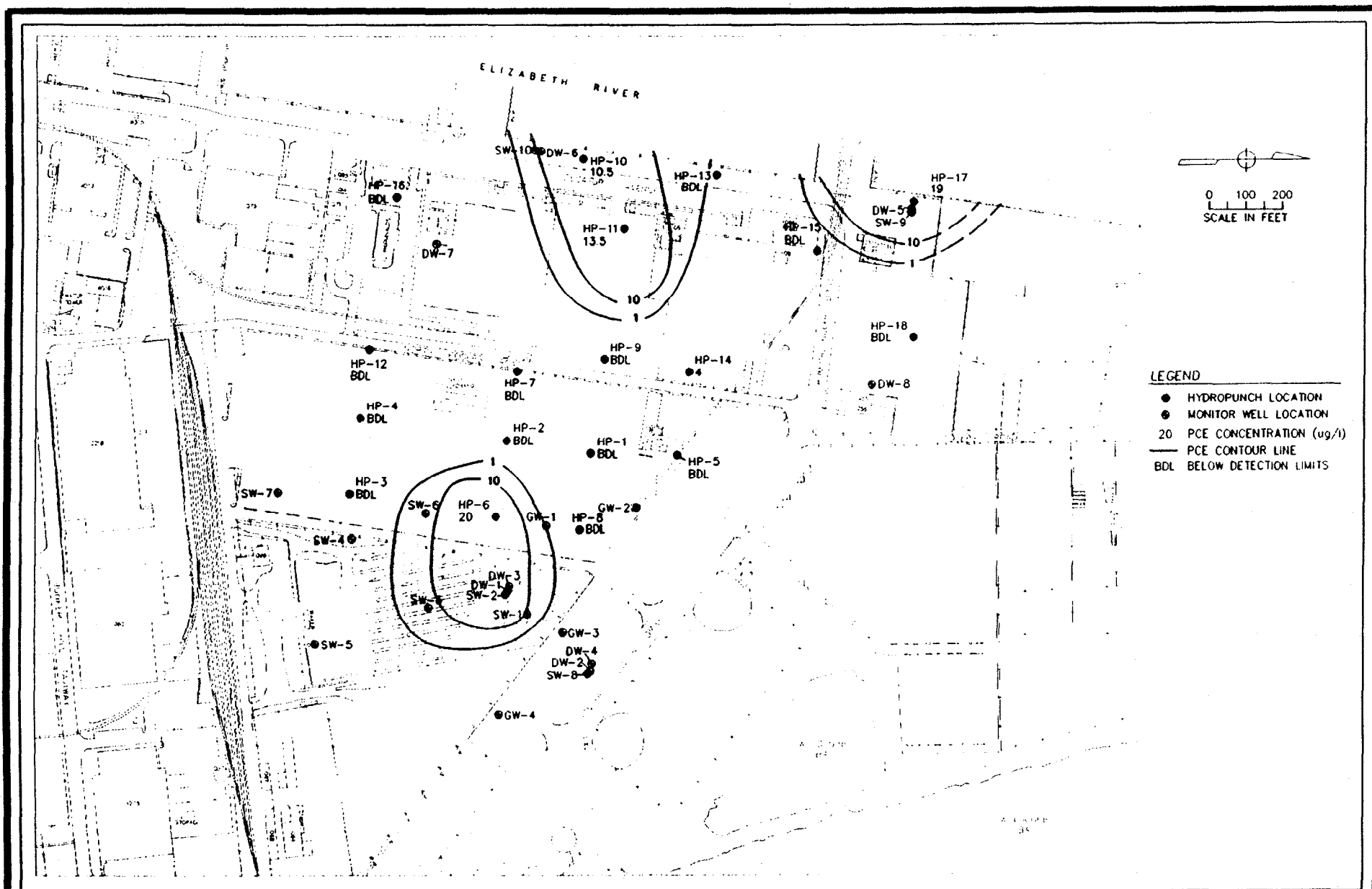


FIGURE 5-29





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Science &  
Engineering

DATE  
3-16-94

SCALE  
SHOWN

TITLE

PCE CONCENTRATION MAP  
AT 25 FEET  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

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LAL/DN

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JOB NO.  
4921150

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QDH / -

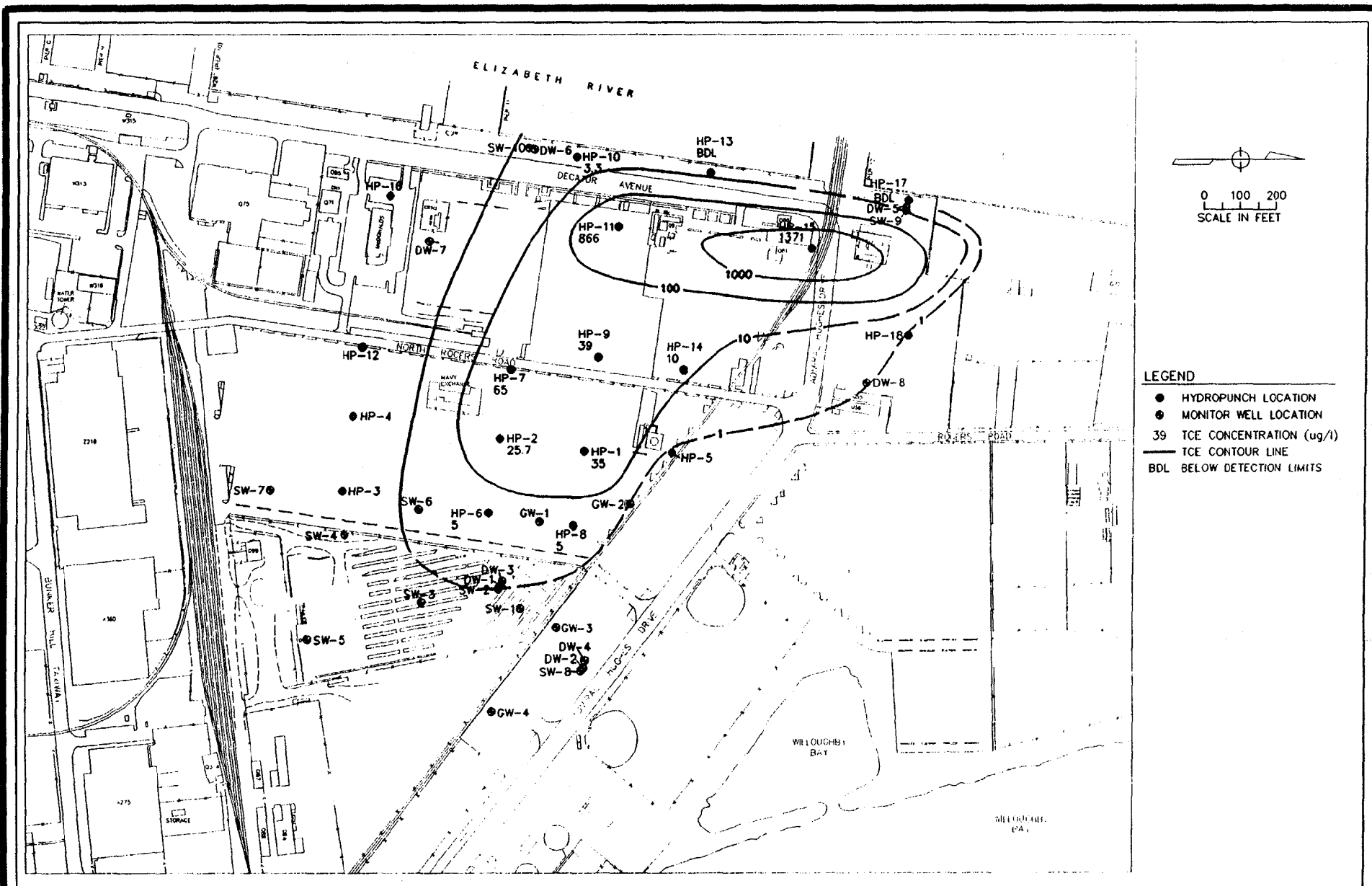
CLIENT

NAVFAC - Q AREA

FIGURE

5-31





**Environmental  
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3-16-94

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JOB NO.  
4921150

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QDF / -

TITLE

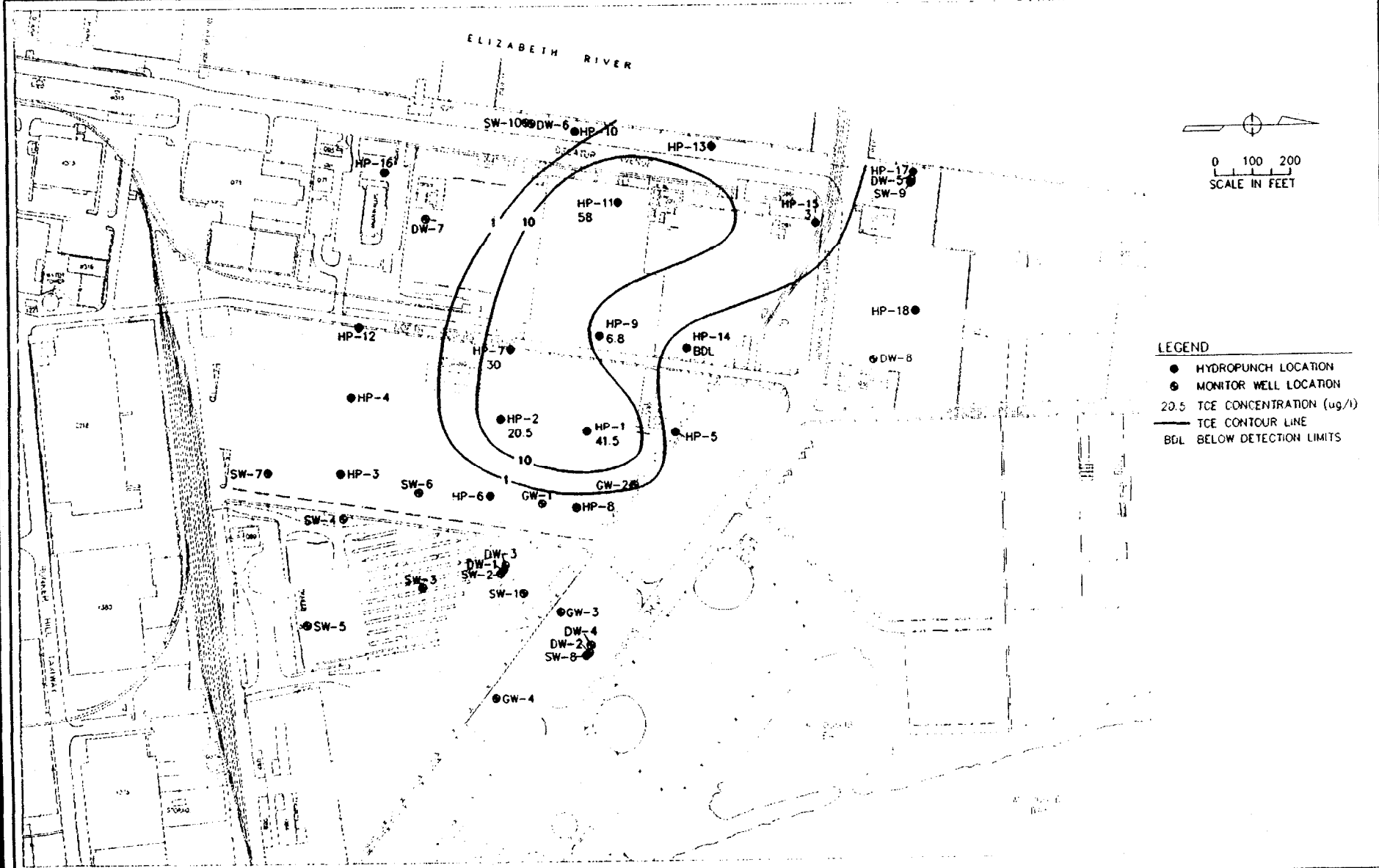
TCE CONCENTRATION MAP  
AT 35 FEET  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE

5-33



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4921150

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SHOWN

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QDE / -

TITLE

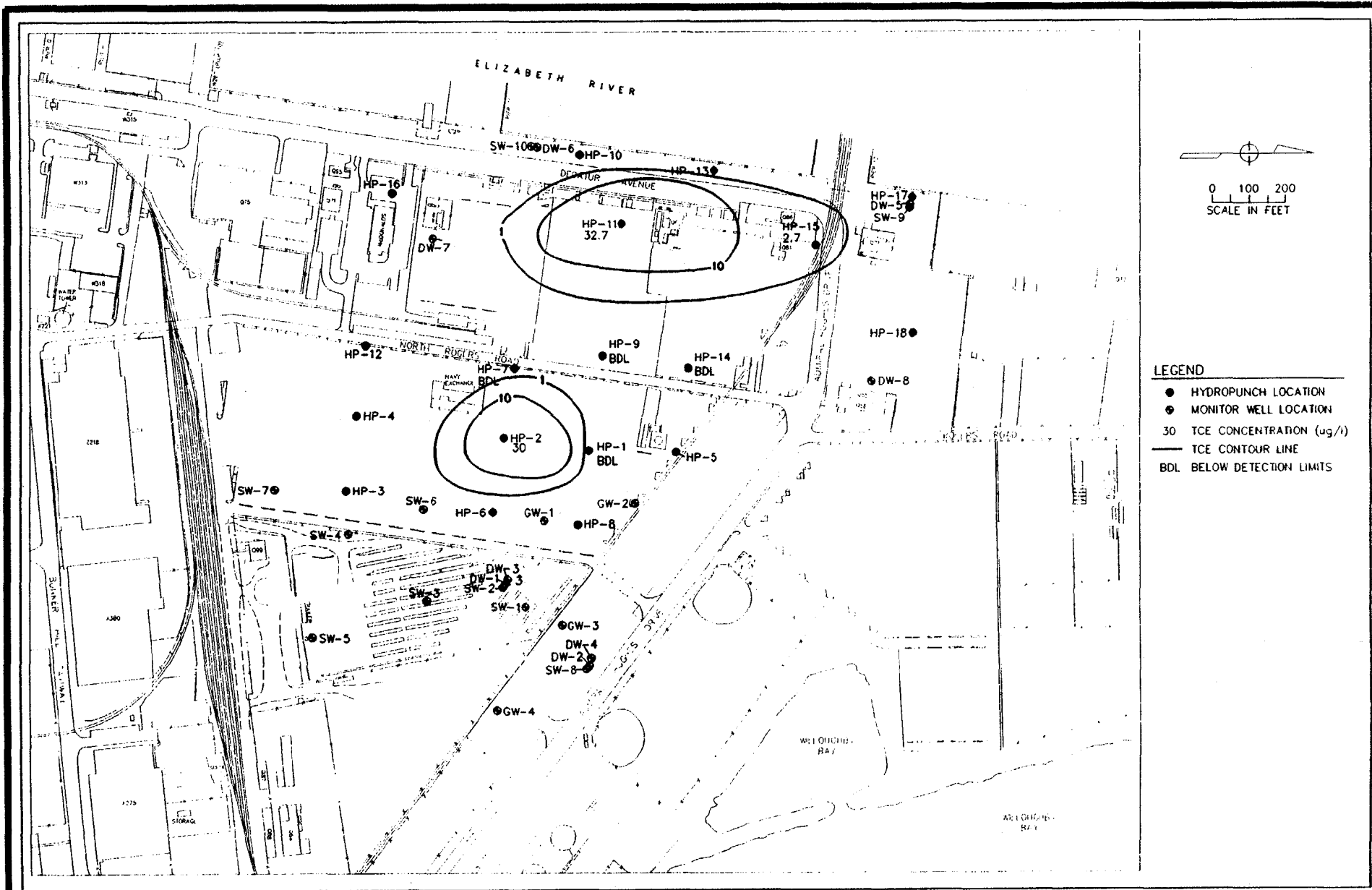
TCE CONCENTRATION MAP  
AT 45 FEET  
Q AREA DRUM STORAGE  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE

5-34



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4921150

SCALE  
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QDD / -

TITLE

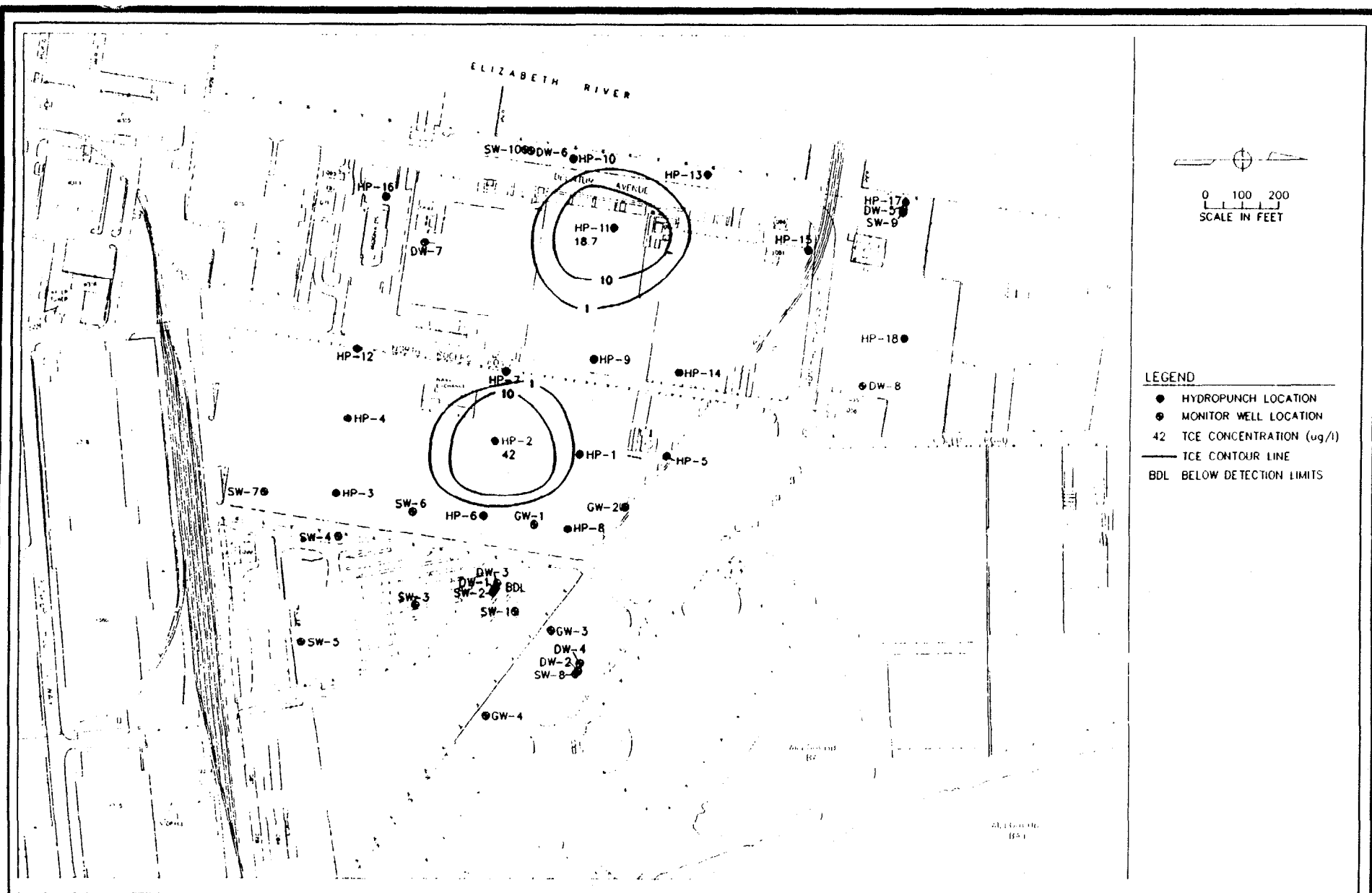
TCE CONCENTRAION MAP  
AT 55 FEET  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE

5-35



Environmental  
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4921150

SCALE  
SHOWN

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DWG. NO./ REV. NO  
QDC / -

TITLE

TCE CONCENTRATION MAP  
AT 65 FEET  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

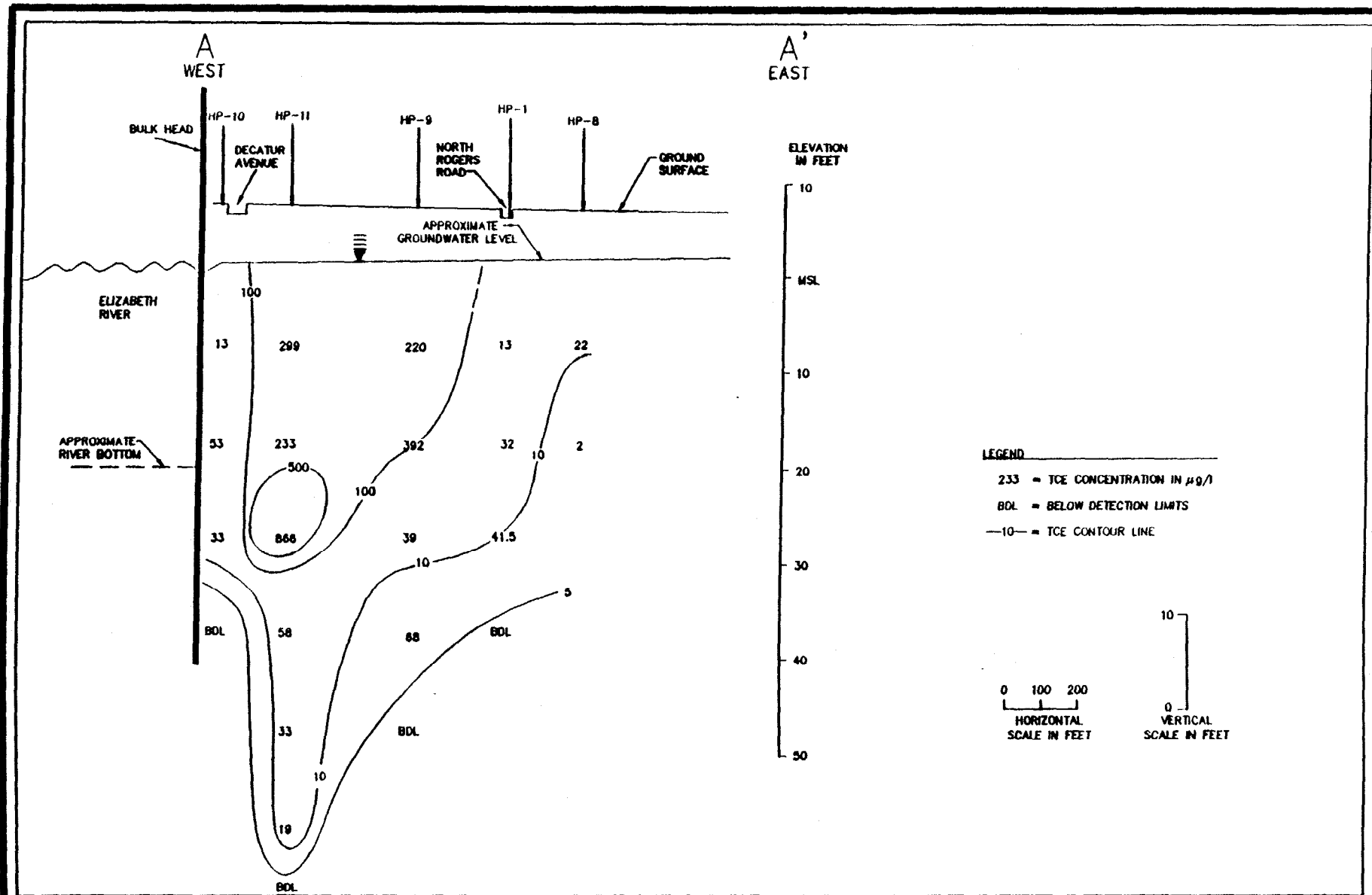
CLIENT

NAVFAC - Q AREA

FIGURE

5-36





**Environmental  
Science &  
Engineering**

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3-16-94

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DN

JOB NO.  
4921150

SCALE  
SHOWN

APPROVED BY

DWG. NO./ REV. NO.  
QDO / -

TITLE

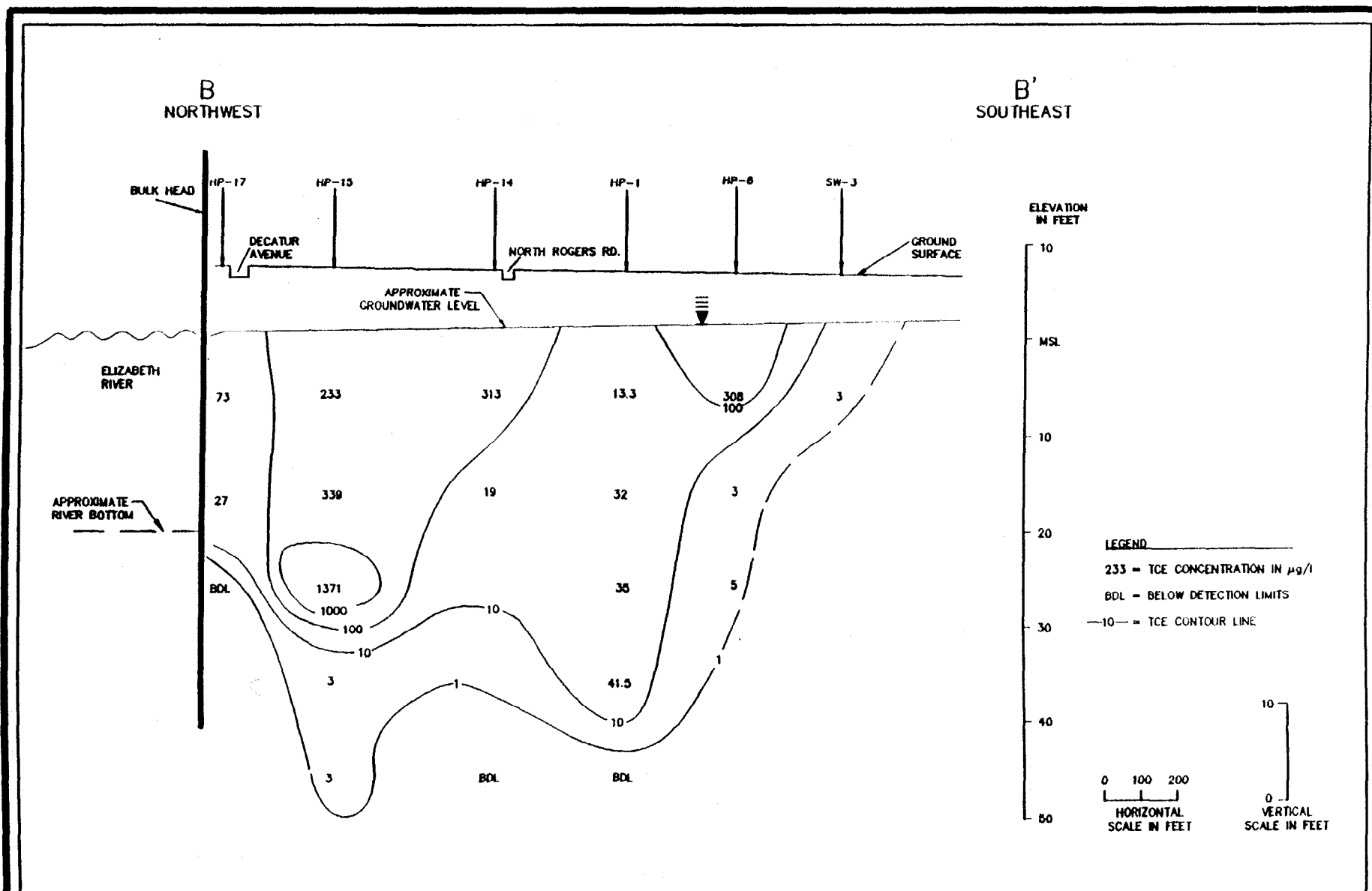
TCE CONCENTRATION  $\mu\text{g/l}$   
CROSS SECTION B-B  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE

5-37



**Environmental  
Science &  
Engineering**

DATE  
3-16-94

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DN

JOB NO.  
4921150

SCALE  
SHOWN

APPROVED BY

DWG. NO./ REV. NO.  
QDP / -

TITLE

TCE CONCENTRATION µg/l  
CROSS SECTION B-B  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE

5-38

## 6.0 RISK ASSESSMENT

### 6.1 Introduction

The QADSY is located on the Norfolk Naval Base and is part of the Sewells Point Naval Complex. It is located in the northwest corner of the complex, within 1200 feet of both the Elizabeth River (to the west) and Willoughby Bay (to the northeast).

The QADSY was created by a fill operation in the early 1950s and was used as a disposal area for dredged materials excavated from Willoughby Bay. The site is a relatively flat, open earthen yard covered by crush-and-run gravel; it is bounded on the north and west by asphalt-paved parking lots. The site was in use from its creation in the 1950s until 1990, and tens of thousands of drums have been stored at the QADSY over the years. A variety of materials were stored in 55-gallon steel drums, including petroleum products (such as oil and lubricants), various organic solvents, paint thinners, formaldehyde, and various pesticides and acids. Throughout the site's history, the northern portion of the yard was used to store damaged and leaking drums.

Section 6.0 is divided into four parts. Section 6.1 is an introduction to risk assessment as it applies to QADSY. Section 6.2 is the Human Risk Assessment (HRA), which contains the following components:

- Identification of chemicals of potential concern (COPCs), including data evaluation and COPC selection,
- Fate and transport analysis (contaminant migration to potential receptor points),
- Exposure assessment, including identification of potential receptor populations and exposure pathways, and calculation of exposure concentrations and chemical intakes,
- Toxicity assessment,
- Risk characterization, and
- Calculation of preliminary remedial goal objectives (RGOs).

Section 6.3 is the Ecological Risk Assessment (ERA), which contains the same six elements as the HRA. A summary of both the HRA and ERA is presented as Section 6.4.

### 6.2 Human Risk Assessment (HRA)

The HRA was conducted based on guidelines developed by the U.S. Environmental Protection Agency (EPA) as outlined in the Risk Assessment Guidance for Superfund (RAGS), Human Health Evaluation Manual, Parts A and B (EPA, 1989b, 1991b), the Dermal Exposure Assessment document (EPA, 1992), the Exposure Factors Handbook (EPA, 1989a), and Region III-specific guidance (EPA, 1993a, 1995b). These procedures conform with RA guidelines released by EPA's Office of Health and Environmental Assessment (EPA, 1986a,b).

### 6.2.1 Selection of Chemicals of Potential Concern (COPCs)

COPCs are the site-related chemicals that may pose health concerns to humans and/or environmental receptors. The data considered in the HRA were taken from ESE and Baker Environmental sampling events (1990-1995) and sampling events from a previous contractor (Malcolm Pirnie, 1983-1986). Chemicals detected at QADSY include volatile organic chemicals (VOCs), semi-volatile organic chemicals (SVOCs), inorganic chemicals (IOCs), and pesticides in soil, and VOCs, SVOCs, and IOCs in groundwater.

#### 6.2.1.1 Data Evaluation

The first step in the COPC selection process is to determine which data will be evaluated in the HRA. The most recent and/or reliable data were used in the COPC selection process and in the calculation of exposure concentrations. The source of the data evaluated is located in Appendix J.

**Soil**--For soil, data from the five samples collected in 1995 were added to the previous soil data as the newer samples were collected from different locations and were analyzed for all priority pollutants. The previous data used includes Malcolm Pirnie data (Pirnie, 1988) for IOCs, pesticides, and miscellaneous SVOCs. During the previous ESE investigation, the majority of the SVOC results were below the limits of detection (DL); however, the DLs reported for the SVOC data were relatively high, limiting the usefulness of this data set. For this reason, the previous ESE SVOC data were disregarded, and the SVOC data from the Malcolm Pirnie report were used. Soil VOC concentrations were based solely on ESE and Baker Environmental data because this data exhibited acceptable DLs according to EPA risk assessment guidance (EPA, 1989b).

**Groundwater**--The groundwater data available for the site include IOCs, an SVOC, and VOCs in the aquifer. Previous samples from the wells located directly on the storage yard were sampled for the full complement of VOCs and IOCs, while the samples collected from locations to the west of the storage yard were analyzed for TCE, PCE, and 1,2-DCA. The primary concern with respect to evaluating groundwater data is the potential for groundwater contaminants to volatilize into indoor air in structures located above the contaminant (TCE and PCE) plumes.

Different data sets were used to evaluate the shoreline concentrations of VOCs and IOCs. The method used for the VOC concentrations was based upon the TCE and PCE plumes in groundwater that have been well delineated at the site and are assumed to represent the area with the highest VOC contamination. A subset of the VOC data from the well locations within the plume areas was developed so that a worst-case estimate of the indoor air impacts could be addressed. The wells included in the evaluation of the VOC concentrations in groundwater were the following: SW-1-1, SW-1-1FD, SW-1-2, SW-2-1, SW-2-2, SW-6-1, SW-6-2, SW-4-1, SW-4-2, DW-1, GW-1-1, GW-1-2.

The TCE and PCE concentrations at the shoreline were well defined; therefore, a subset of the shoreline wells was used to evaluate these two contaminants. The subset of wells that was

used for TCE and PCE shoreline groundwater concentrations included: SW-9, SW-10, DW-5, DW-6, HP-10, HP-11, HP-13, HP-15, and HP-17.

The groundwater IOC data were chosen as a whole because a subset of the data may not be representative of the IOCs at the shoreline. Since the source of the IOCs may not be co-located with the VOCs and the migration of IOC contamination in groundwater may be totally independent of VOC migration, all groundwater data were used to evaluate IOC data.

Eight groundwater samples were collected in 1995 and analyzed for full-scan priority pollutants. The previous data from the eight wells sampled in 1995 were replaced with the new data for those wells. Previous data from the wells not sampled in 1995 were kept in the groundwater data set.

**Data Qualifiers**--Based on EPA guidance (1989b), groundwater and soil data flagged with a "J" (estimated concentration) or "L" (result may be biased low) were used the same way as data that do not have these qualifiers to ensure that a site-related chemical was not overlooked. Groundwater organic data and soil data qualified with a "B" (chemical found in associated blank) were not included in the data set to be evaluated. However, groundwater inorganic data flagged with a "B" was included because in this set of data "B" signifies that the chemical was detected above the instrument DL but below the required method DL. Although the detection is questionable, it has been considered.

#### 6.2.1.2 COPC Selection

**Methodology for Selecting COPCs**--After the appropriate dataset to be evaluated is determined, site-specific COPCs are chosen. COPCs are the site-related chemicals that may pose the most critical health concerns to human health and/or ecological receptors. According to EPA Region III guidance (1993a, 1995b), the first step in selecting COPCs is to reduce the total list of detected chemicals to a more manageable number of chemicals by comparing the maximum detected concentration to a risk-based concentration (RBC). RBCs were developed by Region III for soil, drinking water, air, and fish tissue using protective default exposure scenarios and a target health index (HI) or lifetime cancer risk of 0.1 or  $1 \times 10^{-6}$ , respectively. Such a screening results in a list of COPCs that is limited to contaminants and exposure pathways at a site that are believed to pose the highest potential for adverse impacts to humans and/or ecological receptors.

The RBC screening process is used as follows (EPA, 1993a):

- The maximum concentration of each chemical detected in each medium is compared to the appropriate RBC.
- If the maximum concentration exceeds the RBC for that medium, the chemical is retained in the HRA for all exposure routes involving that medium; otherwise, the chemical is not further evaluated for that medium.
- If a chemical does not exceed its RBC in any medium, the chemical is not further evaluated in the HRA.

- If no chemical in a specific medium exceeds its RBC, the medium is not further evaluated in the HRA.

While this procedure reduces the number of chemicals to be addressed in the HRA, EPA region-wide and Region III guidance requires that a series of activities be conducted following the screening evaluation to ensure that any chemicals eliminated during screening may be re-included based on special properties that are not addressed in the initial screening. These special properties listed in both EPA region-wide and Region III guidance include the following:

- Historical Information--chemicals reliably associated with site activities should be retained;
- Exceptional toxicity--chemicals that are known human carcinogens should be retained;
- Mobility, persistence, or bioaccumulation--chemicals that are mobile, persistent or bioaccumulate, should be retained as the screening process does not address these properties;
- Special exposure routes--some chemicals with significant exposure routes that are not addressed in the screening process (i.e., dermal absorption; ecological exposure);
- Special treatability problems--some chemicals are more difficult to treat than others and, as a result, should remain as COPCs because of their importance during the selection of remedial alternatives;
- ARARs exceedance--chemicals exceeding a chemical-specific ARAR should be retained; and
- Toxicity equivalence of chemical class [e.g., chlorinated dibenzodioxins (CDDs)/chlorinated dibenzofurans (CDFs), PAHs]--chemicals with toxicity equivalents should be retained because this chemical-specific evaluation is not addressed in the screening process.

A summary of the COPC screening process conducted for each exposure medium is described below.

#### **Selection of Soil COPCs**

**Risk-Based Concentration Screening**--As a first step in reducing the number of soil COPCs, the maximum concentration of each chemical detected in soil was compared to a RBC developed using EPA Region III methodology (EPA, 1995b) and the most recent toxicity data available from EPA [Integrated Risk Information System (IRIS), 1996; Health Effects Assessment Summary Tables (HEAST), 1995a; Region III's Risk-Based Concentration Tables, 1995b]. A chemical was removed from the list of COPCs if the maximum detected concentration was less than the RBC for residential soil ingestion.

Of the 59 chemicals detected in site soils, the only chemicals exceeding RBCs were the IOCs arsenic and thallium and the nitroaromatic SVOCs 2,4-dinitrotoluene and N-nitrosodi-n-

propylamine (Table 6-1). Further evaluation of the data showed that several chemicals dropped from the COPC list were known or suspected to have been constituents of materials stored at the site and were detected at concentrations only slightly below the RBC. Following EPA region-wide and Region III guidance (EPA, 1989b, 1993a), several of these chemicals were re-included on the soil COPC list. As several types of petroleum-based compounds were stored at the site, all potentially carcinogenic PAHs were added to the COPC list. These chemicals include benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene. In addition, historical information indicates that pesticides were stored at QADSY; therefore, aldrin, chlordane (alpha- and gamma-), and lindane were re-added to the COPC list. Finally, because no RBCs were available to evaluate calcium, magnesium, potassium, and sodium, these IOCs were re-included on the preliminary COPC list.

In addition to specific contaminants, TPH levels at the site were measured. Although this group of chemicals is useful for determining the extent of petroleum-based contamination, a quantitative risk evaluation is not performed as TPH represents a large group of chemicals that varies from site to site; thus, toxicity criteria are unavailable. While a large percentage of TPH is typically composed of long, straight-chain hydrocarbons of relatively low toxicity, a small percentage of TPH can also be comprised of the more toxic aromatic compounds, such as PAHs. Because PAHs were detected at the site and can be a component of TPH, the carcinogenic PAHs were included as COPCs as a surrogate for evaluating TPH.

Further Reduction in the COPC List--EPA Region III guidance (1993a) states, "Finally,... further reductions in the data set may be justified, based on the status of a contaminant as an essential nutrient, low frequency of detection, or no statistical difference between site and background levels."

The presence of IOCs in onsite samples may or may not be associated with site activities. To determine if IOCs are site-related, the concentrations of inorganic preliminary COPCs are compared to concentrations in samples collected near the site and considered not to be impacted by site contamination. The concentrations of IOCs detected in these samples are referred to as background concentrations. Although Region III Guidance suggests using a background concentration screening, it does not detail a method for performing the screening. Therefore, EPA Region IV guidance (1991e) was followed, which recommends that IOCs be included as COPCs if the maximum concentrations detected onsite are greater than two times the average background concentrations.

Comparisons of the detected concentrations of inorganic preliminary COPCs in site samples to background concentrations are presented in Table 6-2. The maximum concentrations of all the inorganic preliminary COPCs (arsenic, calcium, magnesium, potassium, sodium, and thallium) exceed 2 times the average background level and are retained for further evaluation.

Site-specific background samples were not collected at QADSY. Regional background soil concentrations are available for many IOCs; however, since site "soils" are actually sediments

dredged from a nearby water body, comparison of site concentrations to regional background levels is not appropriate. Baker Environmental, who performed the latest round of soil sampling and analysis at the QADSY, collected background soil borings during their evaluation of the Building LP-20 site, another study area at Norfolk Naval Base. With acceptance from the Navy and Baker Environmental, the results of these background soil samples were used to evaluate the QADSY soil data.

Finally, according to EPA region-wide guidance (1989b):

"Chemicals that are (1) essential human nutrients, (2) present at low concentrations (i.e., only slightly above naturally occurring levels), and (3) toxic only at very high doses (i.e., much higher than those that could be associated with contact at the site) need not be considered further in the quantitative risk assessment. Examples of such chemicals are iron, magnesium, calcium, potassium, and sodium."

A comparison of daily intakes based on the maximum detected concentrations of calcium, magnesium, potassium, and sodium to the minimum Recommended Dietary Intakes (RDAs) for these nutrients is presented in Table 6-3. Because the calculated intakes for each of these inorganics is below the RDA, calcium, magnesium, potassium, and sodium have been removed from the list of soil COPCs.

Final List of COPCs--The final list of soil COPCs is presented in Table 6-5.

### **Selection of Groundwater COPCs**

The selection of groundwater COPCs is similar to the process for choosing soil COPCs. Since the groundwater beneath QADSY is not potable (see Section 6.2.3.2), it was inappropriate to compare chemical concentrations in site groundwater to RBCs developed for tap water ingestion. Instead, the maximum concentration of each chemical detected in groundwater was compared to a RBC developed based on indoor inhalation of chemicals volatilized from groundwater using EPA Region III methodology (EPA, 1995b) and the most recent toxicity data available from EPA (IRIS, 1996; EPA, 1995a, 1995b). A chemical was removed from the list of COPCs if 1) the chemical was nonvolatile or 2) the maximum detected concentration was less than the RBC for residential indoor inhalation.

Of the 33 chemicals detected in site groundwater, the maximum detected concentrations of all twelve VOCs exceeded calculated RBCs (Table 6-4). Therefore, acetone, bromodichloromethane, carbon tetrachloride, chloroform, 1,1-DCA, 1,1-DCE, 1,2-DCEs, methylene chloride, PCE, 1,1,1-TCA, TCE, and vinyl chloride were included on the list of preliminary site COPCs. The maximum detected concentrations of each of these VOCs, except chloroform and 1,1-DCA, also exceeded the EPA chemical-specific maximum contaminant level (MCL). The maximum detected concentrations of eight IOCs and bis(2-ethylhexyl)phthalate also exceeded drinking water criteria (MCLs); however, as these chemicals are not readily volatile and



groundwater beneath the site is not potable, these chemicals were not included on the list of groundwater COPCs.

As none of the organic preliminary COPCs in groundwater are naturally occurring or essential nutrients, the preliminary list of COPCs will not be reduced and represents the final COPC list for groundwater (Table 6-5).

## **6.2.2 Environmental Fate and Transport**

### **6.2.2.1 Physical and Chemical Properties**

The fate and transport processes of the contaminants detected at QADSY are strongly influenced by their physicochemical properties. These properties relate to the environmental partitioning and mobility of the chemicals. Some of these properties also effect the chemical behavior of the compounds and their susceptibilities to degradation induced by physical and biological agents. The physical and chemical properties specific to the exposure concentration modelling performed in the HRA (i.e., groundwater to air concentrations) are described in the exposure concentrations section (6.2.3.3). The following paragraphs offer general information on the different classes of COPCs.

PAHs are typically composed of 4 to 5 benzene rings with molecular weights of over 200 grams per mole (g/mole). They are not very soluble in water, i.e., their solubilities do not exceed 0.01 milligrams per liter (mg/L). The vapor pressure values, which range from  $3.0 \times 10^{-4}$  to  $5.6 \times 10^{-9}$  mm, suggest that these compounds are not volatile. The Henry's Law Constants are generally lower than  $1 \times 10^{-3}$  atm-m<sup>3</sup>/mole indicating that these compounds have a lower tendency to escape from surface waters. The  $K_{oc}$  values are higher than  $1.0 \times 10^5$  milliliters per gram (mL/g), which strongly suggests that the PAHs would be significantly adsorbed by organic materials in the aquatic and subsurface environments.

Compared to PAHs, VOCs are generally more soluble in water. In addition, VOCs have vapor pressures up to six orders of magnitude higher than PAHs. All the VOCs have greater tendencies to escape from the aqueous phase as indicated by the Henry's Law constants greater than  $1 \times 10^{-3}$  atm-m<sup>3</sup>/mole.

Compared to organic contaminants, the specific physicochemical properties of metals vary considerably more, depending on the existing environmental conditions and predominant species of each metal. The halide salts (chloride, bromide, etc.) of several metals, including arsenic, tend to be more soluble than carbonate and hydroxide compounds of these IOCs. The compounds of metals generally dissolve in aqueous phase by forming ions that do not escape into the atmosphere. In some instances, certain species of the dissolved metal ions may be converted into forms that can leave an aquatic system and escape into the atmosphere. Redox-sensitive metals such as arsenic, may exist in alkylated species and become gaseous.

### **6.2.2.2 Environmental Fate Processes**

Several fate processes take place in environmental media and influence the transport and concentration of the organic and metallic contaminants. One process may be closely linked to

another because the phase transfer of a chemical in one medium enhances the transformation process in another different environmental matrix.

This can be illustrated when a contaminant adsorbed on a solid matrix moves into the aqueous phase where a chemical or biological degradation of the contaminant is favored. Important fate mechanisms that can significantly affect the contaminants at the site include microbial degradation, or biotransformation, volatilization, and photolysis. Other fate processes that can influence metals include chemical speciation, sorption, and precipitation.

**Microbial Degradation/Transformation**--Microorganisms such as bacteria and fungi are known to be present in the surface and subsurface environments. They participate in the transformation and biogeochemical cycling of organic compounds and metals. The degradation can either take place under aerobic or anaerobic conditions.

Biodegradation of a PAH with 2 rings or less occurs more rapidly than the biodegradation of PAHs with 3 or more aromatic rings (Perwak *et al.*, 1982). The rate and extent of degradation is variable; however, the mechanism appears to be the removal of one cyclic unit at a time. Some studies showed that PAHs can be microbially metabolized and transformed into other compounds.

Microorganisms can also metabolize VOCs such as chlorinated methane, ethenes, benzene, and chlorobenzene. Parsons and Lage (1984) reported that microbiota degraded PCA and TCA via a reductive dehalogenation pathway under conditions of neutral to acidic pH, and an absence of oxygen and light in a simulated groundwater environment. Results of laboratory studies of Vogel and McCarty (1985) confirmed that PCA can undergo reductive dehalogenation under anaerobic conditions. Both PCA and TCA are converted to DCEs and then to vinyl chloride, which can be eventually mineralized to carbon dioxide. Thus it is possible that vinyl chloride detected at the site could have resulted from the PCA or TCA biodegradation. Carbon tetrachloride can also undergo reductive dechlorination and form chloroform as one of the degradation products (Smith and Dragun, 1984; Galli and McCarty, 1989).

Benzene and chlorobenzene are also known to be metabolized by microbes. A mutant of *Pseudomonas putida* can transform benzene to catechol (Dagley, 1972). Bacterial dioxygenases can in turn cleave catechol to yield acid and aldehyde (Chapman, 1972). For chlorobenzene, unacclimated aerobic river die-away tests indicate that aqueous biodegradation is possible.

Bacteria, yeast, and fungi can catalyze the modification of metals in the environment. These transformations from one form of a metal or element to another affect the concentration and distributions of the metallic pollutants. The microbial transformation processes generally observed include redox, alkylation, dealkylation, and sulfide precipitation.

Alkylation or methylation of arsenic can be catalyzed by microorganisms as part of a detoxification mechanism. Arsenic can be methylated by bacteria and fungi to yield dimethyl and trimethylarsines (McBride and Wolfe, 1971; Saxena and Howard, 1977; Thayer and Brinckman, 1982). The reverse process, dealkylation is also possible and has been studied in systems involving arsenic.

**Volatilization**--Volatilization is a process of mass transfer of the contaminants from the aqueous phase to the air or atmosphere. Chemicals with a Henry's Law constant of greater than  $1 \times 10^{-3}$  atm-m<sup>3</sup>/mole have a greater tendency to volatilize.

PAHs, due to their low Henry's Law constants and vapor pressures, are not expected to escape readily from solution to the air. Thus, volatilization is considered to be slow and less important for this group of compounds.

Volatilization is an important fate process for the VOCs. The rate of mass transfer or loss from an open water body would be affected by surface and bulk agitation of the liquid medium, wind velocity, and temperature. The presence of suspended matter and particulates in the water, to which the chemicals can sorb, will influence volatilization.

SVOCs would not be expected to volatilize readily owing to their low Henry's Law Constants. In an aquatic environment, these compounds will tend to be preferentially adsorbed, thus remaining in only small mass quantities in the aqueous phase.

The inorganic forms of arsenic and thallium present in the aqueous phase are not expected to volatilize. However, the microbial methylation process described previously can transform arsenic into volatile species under certain environmental conditions. For instance, arsenic can be converted to di- and trimethylarsines that escape from natural waters. The rate of volatilization may be retarded by other processes such as adsorption and chemical degradation during the upward diffusion of the volatile species from the sediments and underlying water column to the air.

**Photolysis**--Chemicals present on the soil surface and natural waters can undergo chemical degradation by absorbing solar energy. The energy can excite the molecule of the contaminants leading to bond cleavage and formation of photolysis products.

**PAHs**--Many of the PAHs detected have 4 to 5 aromatic rings which are susceptible to photolytic degradation. One of the most widely studied compounds is benzo(a)pyrene which has been reported to undergo photolysis by light with wavelengths in the solar region and yield mixture of quinones. The fate process is believed to be mediated by single oxygen molecules which are formed through energy transfer from the electronically excited aromatic molecule in its triplet state (Andelman and Suess, 1970; NAS, 1972; Neff, 1979). The rate of photolysis can be affected by the presence of natural organic and inorganic substances in solution. The photolytic degradation of benzo(a)pyrene was found to be inhibited in natural

waters with humic acids. Inhibition of photolysis was also observed when benzo(a)pyrene was adsorbed onto kaolinite clay.

Other PAHs would be expected to exhibit photolytic behavior comparable to that of benzo(a)pyrene. Chrysene was reported to be potentially susceptible to photolysis and yield quinones based on studies involving structurally related compounds such as benzo(a)pyrene (EPA, 1985).

VOCs--Based on an EPA (1979) review, photolysis is considered too slow to be a significant factor in influencing the fate of VOCs. No data were found to suggest that PCE or TCE undergo photodegradation; however, benzene might be photolytically degraded. However, the half life of the process is believed to be longer. It is likely that the other VOCs such as carbon tetrachloride, vinyl chloride, and chlorobenzene would exhibit similar photolytic behavior, unless new data or future studies indicate otherwise.

IOCs--No information was found during a literature survey to indicate that photolysis is an important fate process affecting the concentration and distribution of the metals in the environment.

#### **6.2.2.3 Contaminant Migration Pathways**

The organic compounds and metals present in the soils at QADSY have the potential to migrate to other environmental media and eventually to move toward downgradient locations. The five possible migration pathways are: (1) soil-to-groundwater, (2) soil-to-surface water, (3) soil-to-air, (4) surface water-to-air, and (5) groundwater-to-air. The rate and extent of migration of the contaminants will be strongly influenced by their physicochemical properties and existing onsite environmental conditions. In this section, the different migration pathways are described.

**Soil-to-Groundwater Pathway**--During and after a rainfall event, water moves on the soil surface as surface runoff and infiltrates the soil. Leachate percolates the subsurface environment, the water carries with it dissolved organic chemicals, soluble metallic species, and compounds adsorbed to suspended matter in the aqueous phase. Those chemicals strongly sorbed to suspended matter, such as those with high adsorption coefficients ( $K_{oc}$  or  $K_d$ ), would be expected to be retained by the upper few inches or feet of the surficial soil. The dissolved forms can continue migrating downward. However, only a certain fraction of the total dissolved compounds is expected to reach the groundwater because adsorption, and other dissipation mechanisms may still continue as the solution passes through the vadose zone and finally reaches the aquifer. The extent of adsorption will be affected by the chemical structure, charge of metallic species, presence of competing species, and hydrogeological factors such as porosity, soil texture, depth to water table, and presence of layers with low hydraulic conductivity. In some instances, solution chemistry factors such as pH, redox potential, and ionic strength may exert significant influence on leaching.

**Soil-to-Surface Water Pathway**--Part of the rain water that does not percolate can move over the surficial soil to low-lying areas as surface runoff. This runoff can transport the dissolved chemicals and metallic species from the source areas to drainage systems and nearby surface water bodies such as streams and creeks. In addition, metals and organics sorbed onto particulates or coated onto moving soil particles can be transported with the surface runoff. As the surface water moves or stagnates in certain locations, some speciation and transformation of metals can occur depending on the pH, presence of oxidizing and reducing agents, levels of organic matter and inorganic ligands picked up during the transport. Organic compounds in standing water runoff can potentially undergo photolysis and volatilization.

**Soil-to-Air Pathway**--Organic contaminants and metals in the ground surface and near the surficial soils can be released into the atmosphere either by volatilization, fugitive dust, or particulate emission. Compounds such as VOCs would be expected to be lost by volatilization. For compounds with low vapor pressure and high  $K_{oc}$ , volatilization is considered to be of lesser importance. However, these compounds, along with metallic species sorbed onto fine soil particulates, may be released to the air via dust or particulate emission due to wind-driven currents or other mechanical disturbances of the surface soil (i.e., through human activities). This mechanism of contaminant transport, however, may not become a significant pathway if the contaminated surface soil is covered by grass and other barriers.

**Surface Water-to-Air Pathway**--Contaminants that eventually reach surface water bodies, such as streams and creeks, have the potential to migrate to the atmosphere. These contaminants are usually VOCs that have relatively high vapor pressures and Henry's Law Constants ( $>1 \times 10^{-3}$  atm-m<sup>3</sup>/mole). The volatilization loss rate would be influenced by surface and bulk agitation, wind current, temperature, and presence of materials in the aqueous phase that inhibit the actual mass transfer to the atmosphere. Volatile contaminants, such as VOCs, reaching the atmosphere can undergo fairly rapid photooxidation with hydroxyl radicals.

**Groundwater-to-Air Pathway**--Volatile contaminants in the groundwater can diffuse through the soil pore spaces and finally reach the soil surface and surrounding air. This subsurface volatilization pathway is affected by depth to the water table, moisture content of the soil column, and soil texture of the vadose zone. When the moisture content is low, the water table is shallow, and the soil is predominantly sandy, volatilization from the groundwater is highly favored to occur. When the air porosity is low, water table is deep, and moist silt and clay abound in the unsaturated soil column, groundwater-to-air pathway would not be significant.

### 6.2.3 Exposure Assessment

The exposure assessment uses information obtained from the site characterization and the environmental fate and transport analysis to identify significant complete exposure pathways and to estimate actual or potential COPC concentrations for each exposure pathway. Behavioral or physiological factors influencing exposure frequency and exposure levels are then presented in a series of exposure scenarios as a basis for quantifying chemical intake levels by receptor populations for each significant completed exposure pathway. Results of the

exposure assessment are used in conjunction with the information summarized in the toxicity assessment to determine the potential human health risks associated with the site.

#### **6.2.3.1 Receptor Identification**

The human receptors for which risks are evaluated are current worker, future worker, and future resident. A current worker is assumed to work in and around the storage shed on an infrequent basis. The future worker is evaluated in the event the area above the contaminant plume is developed into a standard work area in which employees are exposed on a daily basis. The future residential scenario is highly unlikely due to the industrial nature of the site; however, as requested by EPA Region III, the risks are being evaluated to account for all potential land use scenarios. Due to the facility's "open gate" policy, the potential for a trespasser to be present at the site does exist. However, because the frequency of exposure of a trespasser would be less than that of the future worker, the future worker scenario is considered a more conservative evaluation than a trespasser scenario.

#### **6.2.3.2 Exposure Pathways**

An exposure pathway is the route over which a chemical or physical agent migrates from a contaminant source to an exposed population or individual (receptor) and also describes a unique mechanism by which the receptor may be potentially exposed to chemicals or physical agents at or originating from the site. For an exposure pathway to be complete, the following four elements must be present:

- A source or release from a source (e.g., vapor emissions released from groundwater to air);
- A likely environmental migration route (e.g., volatilization of a site-related chemical or physical agent);
- An exposure point where receptors may come in contact with site-related chemical or physical agents (e.g., local creek); and
- A route by which potential receptors may be exposed to a site-related chemical or physical agent (e.g., inhalation of vapors).

If any of these four elements is not present, the exposure pathway is considered incomplete and is not expected to contribute to the total exposure from the study area. A screening of each exposure pathway element was conducted for each area of interest to identify significant completed exposure pathways. This screening ensures that the risk characterization focuses only on the completed exposure pathways and eliminates from further consideration those pathways that are incomplete. Each of the four components of the potentially completed exposure pathways is discussed in the following sections. The exposure equations and factors used for the HRA are described in Appendix K.

**Water Consumption Pathway**--Domestic groundwater consumption is a pathway of concern when humans use private wells that tap into the underlying groundwater close to a site. Exposure would occur as a result of ingestion, inhalation, and direct dermal contact with chemicals during domestic activities. Due to the high salinity of the water below the QADSY

the water is not potable; therefore, the groundwater ingestion pathway is not complete. The domestic water in the vicinity of the site is supplied by the City of Norfolk Water Authority. Under the guidance of State and Federal regulatory agencies, the decision has been made to exclude the pathway of groundwater ingestion from the quantitative risk assessment. A more complete discussion of the exclusion of site groundwater as a potable water source is given in the following paragraphs.

Justification for the Exclusion of Site Groundwater as a Potable Water Source--Electrical conductivity ( $\mu\text{mho/cm}$ ), pH, temperature ( $^{\circ}\text{C}$ ) and sample depth were measured in 47 water samples from the water table aquifer near and to the west and northwest of the site. Total dissolved solids (mg/L) concentrations was estimated from these measurements using a method provided by Perkin and Lewis (1980).

pH ranged from 6.8 to 9.8 with an average of 7.6. Temperature ranged from 9.6 to 18.9  $^{\circ}\text{C}$  with an average of 14.6 C. Sampling depth ranged from 15 to 75 ft below land surface. Conductance ranged from 103 to 4680  $\mu\text{mho/cm}$  with an average of 1424  $\mu\text{mho/cm}$ . Within the observed range of temperature and sample depth, total dissolved solids (mg/L) equals approximately 0.7 times conductance ( $\mu\text{mho/cm}$ ; the ratio can range from 0.65 to 0.85 within this temperature and depth range), and the estimated concentrations of total dissolved solids (TDS) ranged from 82 to 3,450 mg/L with an average of 976 mg/L. The average exceeds the state of Virginia secondary drinking water standard of 500 mg/L and indicates a brackish water.

Sixty two percent of the individual samples also exceeded the secondary drinking water standard. Total dissolved solids appear to increase slightly with depth as would be expected in a zone where fresh infiltrating rainwater is mixing with saltwater intruding from the James River estuary. Samples collected within 10 feet of the water table exhibited an average TDS of 458 mg/L; samples from 10 to 30 feet below the water table averaged 1,120 mg/L TDS; and samples from more than 30 ft below the water table averaged 1,109 mg/L. This apparent trend of increasing salinity with depth was not statistically significant, however. Of the ten samples collected within 10 ft of the water table, five (50 percent) exceeded the secondary drinking water standard. In addition, 11 percent of all samples exceeded 2,000 mg/L TDS, a level that would definitely taste salty and be unacceptable as a water supply for livestock.

Pumping of this aquifer for water supply would be expected to increase the TDS levels by encouraging further saltwater intrusion, thereby negating the use of this aquifer as a potable supply.

**Soil Direct Contact Pathway**--Although the majority of the site is paved and gravel-covered, the potential for intermittent exposure of persons currently working at the QADSY to contaminated soil does exist and is evaluated in this RA. In addition, future industrial and residential land use options are evaluated to provide a more conservative estimate of potential, though unlikely, future exposure.

**Soil Ingestion Pathway**--The majority of the site is paved and gravel-covered; however, the potential for intermittent exposure of persons currently working at the QADSY to contaminated soil does exist and is evaluated in this RA. The soil ingestion pathway is based on direct ingestion of contaminated surficial soils and may occur during hand-to-mouth activities, such as eating or smoking while at the site. This pathway is considered to be complete and is evaluated in this RA for a current worker. In addition, future industrial and residential exposures are evaluated to provide a more conservative estimate of risk associated with potential, though unlikely, future land use.

**Inhalation Pathway**--Inhalation can occur from exposure to fugitive dusts from surficial soils and from exposure to contaminated air due to volatilization of COPCs from soil and/or groundwater. Inhalation of VOCs in air may occur as a result of chemicals volatilizing from the underlying aquifer. Exposure by inhalation is expected to be negligible outdoors but may be significant indoors where vapors cannot readily disperse (e.g., onsite buildings). Inhalation exposure to COPCs that volatilize from groundwater and subsequently accumulate in onsite buildings is considered to be a complete pathway and is quantified in this HRA. As the site is covered with asphalt and gravel and the remainder is scheduled to be paved in the near future, inhalation of fugitive dusts is not considered a complete pathway and is not quantified in this HRA.

#### **6.2.3.3 Exposure Concentrations**

Exposure concentrations are the contaminant concentrations that a receptor may contact at the site. Exposure concentrations are the lesser of the maximum detected concentration and the upper 95th confidence limit of the mean (UCL<sub>95</sub>). This procedure is in accordance with RAGS (EPA, 1989b), which states that if there is great variability in measured concentration values, the UCL<sub>95</sub> will be high, and conceivably could be above the maximum detected value. As a result, in these cases EPA recommends that the maximum detected value be used to estimate exposure concentrations (EPA, 1989b). Therefore, in accordance with RAGS, the exposure concentrations that are used in risk characterization are the lowest of the maximum and UCL<sub>95</sub> values.

For those constituents with concentrations below DLs, one-half of the DL ( $\frac{1}{2}$ DL) was used in the calculation. Because the UCL<sub>95</sub> calculation uses values for undetected constituents that are equal to  $\frac{1}{2}$ DL, the calculated UCL<sub>95</sub> can be significantly affected by samples where matrix interferences have resulted in sample dilution and significantly elevated DLs have been reported. In some instances, these elevated DLs result in a UCL<sub>95</sub> exceeding the maximum concentration of the constituent detected. In these cases, the maximum detected concentration instead of the UCL<sub>95</sub> was used for quantifying health risks (Appendix J).

Constituents that were detected at equivalent concentrations in field samples and laboratory or field blanks were not included in the risk analysis.

The data used in the RA were taken from ESE and Baker Environmental sampling events (1990-1995) and sampling events from the previous contractor (Malcolm Pirnie, 1983-1986).



The most recent and/or validated data were used in the calculation of the exposure concentrations for the RA. The following paragraphs explain the methodology used for calculating exposure concentrations and also what data gaps were found during the data evaluation process. A discussion as to what steps were taken to assure the highest possible integrity of the data used in the risk calculations is also included in this section.

**Soil Exposure Concentrations--**The 1995 data and the Malcolm Pirnie data were used for the calculation of IOC, SVOC, and pesticide soil exposure concentrations. During the previous ESE investigation, the majority of the SVOC results were below the limits of detection. The DLs reported for the SVOC data were relatively high, limiting the usefulness of this data set. For this reason, the previous ESE SVOC data was disregarded. Exposure concentrations for soil VOCs were based solely on 1995 data because this data exhibited acceptable DLs and was collected more recently (VOCs are not persistent in surface soils).

TCLP data for soils at the site were collected during one of the sampling rounds to determine the characteristics of the soil for disposal purposes. These data, although useful for determining the leachability of contaminants, do not provide information useful in estimating the exposure concentration of chemicals in surficial soil at the site. Therefore, the TCLP metal data were not used in the determination of metal exposure concentrations in soil. Due to a lack of toxicity data on groups of contaminants, the TPH data are being evaluated qualitatively.

A summary of the soil exposure concentrations is presented in Appendix J, Table J-1. A listing of the samples used to calculate the soil exposure concentrations is presented in Appendix J, Table J-3.

**Groundwater Exposure Concentrations--**The groundwater data available for the site include VOCs and IOCs in shallow and deep aquifers. The wells located directly on the storage yard were sampled for the full complement of VOCs and IOCs. The samples collected from locations to the west of the storage yard were analyzed for TCE, PCE, and 1,2-DCA. Because 1,2-DCA was not detected in any of the groundwater samples, TCE and PCE were expected to be the most significant COPCs at the site.

As potable use of groundwater under the site is not a completed exposure pathway, the primary concern for groundwater contamination is the potential for groundwater VOCs to volatilize into indoor air in structures located above the TCE and PCE plumes.

The methodology for estimating VOC concentrations was slightly different than the method used for estimation of the IOC concentrations. The method used for the VOC concentrations was based upon the TCE and PCE plumes in groundwater that have been well delineated at the site and are assumed to represent the area with the highest VOC contamination. A subset of the VOC data from the well locations within the plume areas was developed so that a worst-case estimate of the indoor air impacts could be developed. The wells included in the calculation of the UCL<sub>95</sub> concentrations for all VOCs except PCE and TCE in groundwater

were the following: SW-1-1, SW-1-1FD, SW-1-2, SW-2-1, SW-2-2, SW-6-1, SW-6-2, SW-4-1, SW-4-2, DW-1, GW-1-1, GW-1-2.

The TCE and PCE concentrations at the shoreline were well defined; therefore, a subset of the shoreline wells was used to determine the  $UCL_{95}$  concentrations for these two contaminants. The subset of wells that was used for TCE and PCE shoreline groundwater concentrations included: SW-9, SW-10, DW-5, DW-6, HP-10, HP-11, HP-13, HP-15, and HP-17. Shallow and deep samples taken from these locations were used to model the TCE and PCE concentrations under the building of concern (the storage shed). These groundwater concentrations were used to model the indoor air concentrations in that building.

The IOC groundwater data were chosen as a whole because a subset of the data may not be representative of the IOCs at the shoreline. Since the source of the IOCs may not be co-located with the VOCs and the migration of IOC contamination in groundwater may be totally independent of VOC migration, all groundwater data were used to calculate a  $UCL_{95}$  value for use in the surface water and sediment concentration modelling.

A summary of the groundwater exposure concentrations is presented in Appendix J, Table J-2. A listing of the samples used to calculate the groundwater exposure concentrations is presented in Appendix J, Table J-3.

**Indoor Air Exposure Concentrations--** Volatile contaminants at the site may volatilize from the groundwater into the indoor air of buildings located over the groundwater plumes. Volatilization of COPCs from the groundwater into onsite buildings is expected to be more significant than volatilization from soil.

It is possible that COPCs in groundwater below the buildings may volatilize via the unsaturated soil and accumulate in building air. To evaluate air exposure concentrations in the buildings, the following relationships are used (Tucker and Hearne, 1989; Jury *et al.*, 1983):

$$F = \frac{na^{10/3} \times Da \times H \times C_{gw} \times 10^{-3}}{n^2 \times h_{gw}} \quad (6-1)$$

Where:

- F = flux (mg/yr-cm<sup>2</sup>),
- na = soil air porosity = 0.20 (USGS, 1983),
- Da = diffusion coefficient in air (cm<sup>2</sup>/yr) (Table 6-6),
- H = dimensionless Henry's Law constant (Table 6-6),
- C<sub>gw</sub> = groundwater exposure concentration (mg/L) (Table 6-6),
- n = soil porosity = 0.25 (USGS, 1983),
- h<sub>gw</sub> = depth to groundwater = 244 cm (RI), and
- 10<sup>-3</sup> = conversion factor (L/cm<sup>3</sup>).

The flux of a particular COPC (from Equation 6-1) is used in the following relationship (Tucker and Hearne, 1989) to determine the concentration of air at the buildings:

$$C_{air} = F \times \frac{TAC}{VAR} \times 10^6 \quad (6-2)$$

Where:

- $C_{air}$  = office air concentration [milligrams per cubic meter ( $\text{mg}/\text{m}^3$ )],
- TAC = the time of exchange for the building air,  
=  $1.096 \times 10^{-4}$  years/exchange for commercial/industrial buildings (Ronnberg *et al.*, 1990),
- VAR = the ratio of the building volume to the surface area in contact with the soil (i.e., VAR equals the height of the building)  
= 305 cm, and
- $10^6$  = conversion factor ( $\text{cm}^3/\text{m}^3$ ).

Using the corresponding chemical-specific parameters from Table 6-6 in Equations 6-1 and 6-2, air exposure concentrations are calculated for the COPCs in the onsite building and are presented in Table 6-6.

#### 6.2.3.4 Intake Estimates

Chemical intake is the amount of the chemical contaminant entering the receptor's body. To estimate a reasonable maximum exposure (RME), upperbound (upper 90<sup>th</sup> or 95<sup>th</sup>) percentile exposure concentrations and factors were used, where available. The formulas used to calculate human pathway-specific chemical intakes were based on the generic intake equation presented in RAGS (EPA, 1989b):

$$I (\text{mg/kg/day}) = \frac{C * CR * EF * ED}{BW * AT} \quad (6-3)$$

Where:

- I = intake, the amount of chemical at the exchange boundary;
- C = chemical concentration, the average concentration contacted over the exposure period (e.g.,  $\text{mg}/\text{L}$  for groundwater);
- CR = contact rate, the amount of contaminated medium contacted per unit time or event [e.g., liters per day ( $\text{L}/\text{day}$ )];
- EF = exposure frequency (days/year);
- ED = exposure duration;
- BW = body weight, the average body weight of the exposed individual [kilogram ( $\text{kg}$ )]; and
- AT = averaging time, period over which exposure is averaged (days).

Potential onsite receptors are current and future workers and future residents who may be exposed to outdoor soils and air in onsite buildings. Airborne COPCs are presumed to originate in the groundwater contamination.

Oral and dermal soil intakes are determined using soil exposure concentrations (Appendix J, Table J-1) with the corresponding exposure equation and parameters presented in Appendix K. Inhalation intakes are determined using building air exposure concentrations (Table 6-6) with the corresponding exposure equation and parameters presented in Appendix K. Resultant intake values are calculated to determine potential noncarcinogenic and carcinogenic effects in human receptors and are presented in Appendix L.

#### **6.2.4 Toxicity Assessment**

The toxicity assessment section of the RA weighs the available evidence regarding the potential for a particular chemical to cause adverse effects in exposed individuals, and provides an estimate of the extent of exposure and possible severity of adverse effects. The assessments used to develop toxicity values consist of two steps: (1) hazard identification, and (2) dose-response assessment. The hazard identification determines the potential adverse effects associated with exposure to a chemical along with the types of potential health effects involved. In the dose-response assessment, quantification of the toxicity values and estimation of reference dose values are performed.

Since most of the COPCs detected at QADSY are well studied, toxicological assessments and water-quality criteria technical documents prepared by EPA served as the primary information sources on pharmacokinetics and human health effects. Toxicity factors [cancer slope factors (CSFs) for carcinogens and reference doses (RfDs) for noncarcinogens] presented in this section reflect the most current toxicological information available from EPA (IRIS, 1996; EPA, 1995a, EPA, 1995b) and other sources. These factors are used to estimate risk and HI values in the risk characterization.

The exposure levels of chemicals observed at QADSY are more relevant to a chronic exposure scenario, as none of the identified contaminants are at high enough levels to warrant an acute or a subchronic toxicity criteria application. A list of all the criteria used for the relative risk calculations is included in Table 6-7. The RfDs and CSFs presented in this table are the values provided in IRIS (1996), HEAST (EPA, 1995a), and other sources and have been rounded to two significant figures. A description of carcinogenic weight-of-evidence (WoE) classifications for potential carcinogens is presented as Table 6-8.

##### **6.2.4.1 Toxicity Information for Noncarcinogenic Effects**

An RfD is an estimate (with uncertainty spanning approximately an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects if experienced continuously during a lifetime and is the toxicity value most often used to evaluate the noncarcinogenic impacts from exposure to chemicals. RfDs are specific to the route of exposure (i.e., an inhalation RfD is used for inhalation exposure), critical effect (developmental or systemic), and the length of

exposure evaluated. Chronic RfDs are specifically developed to be protective against long-term exposure to a chemical. Subchronic RfDs are developed to characterize potential noncarcinogenic effects associated with shorter-term exposures. The derivation procedure for an RfD can be found in RAGS, Part A (EPA, 1989b) or other technical guidance documents for criteria development.

The list of COPCs for the HRA and their respective RfDs are presented in Table 6-7. The RfDs listed are the chronic RfDs, as Superfund guidance requires use of chronic exposure dose (RfD) levels. Chronic RfDs are applicable because: 1) the contaminant concentrations typically found at Superfund sites are low, and 2) the expected intake rate of contaminants is similar to the chronic dose levels administered to experimental animals in chronic toxicity studies.

#### **6.2.4.2 Toxicity Information for Carcinogenic Effects**

A CSF and the accompanying WoE determination are the toxicity data most commonly used to evaluate potential human carcinogenic risks. The methods used by EPA to derive CSFs or unit risks are described in RAGS, Part A (EPA, 1989b). For carcinogens, EPA usually assumes a nonthreshold response, or that at every dose level of a carcinogen there is some amount of adverse response; no dose is believed to be risk-free. For carcinogens, EPA uses a 2-part evaluation; determination of a WoE classification and calculation of a CSF.

Generally, a CSF is a plausible upperbound estimate of the probability of a response per unit intake of a chemical over a lifetime. Toxicity to carcinogens can be expressed in several ways. The CSF is usually the 95 percent upper confidence limit ( $UCL_{95}$ ) of the slope of the dose-response curve and is expressed as  $(\text{mg/kg/day})^{-1}$ . Toxicity values for carcinogenic effects can also be expressed as risk per unit concentration of the substance in the medium of exposure, referred to as unit risks.

Toxicity profiles for the final COCs [those chemicals contributing 1) a risk of  $\geq 1\text{E-}6$  to a total risk of  $\geq 1\text{E-}4$  or 2) an HQ of  $\geq 0.1$  to an HI of  $\geq 1$ ] are presented in Appendix N.

#### **6.2.4.3 Chemicals with Unavailable EPA Toxicity Values**

**Carcinogenic Chemicals With No Established CSFs**--Several of the organic chemicals found at QADSY are either known, suspected, or possible human carcinogens. A list of CSFs and WoE classifications for the carcinogens identified at QADSY is presented in Table 6-7.

Of the organic chemicals detected at QADSY, 1,1-DCA is classified as a Group C possible human carcinogen but does not have an EPA-determined oral or inhalation CSF; therefore, only the noncarcinogenic hazards associated with exposure to this organic chemical is evaluated.

Also, no inhalation URs or CSFs have been developed for the Group B2 suspect human carcinogens 2,4-dinitrotoluene, N-nitrosodi-N-propylamine, lindane, or bromodichloromethane.

These chemicals are evaluated for oral carcinogenicity only. The oral CSF used for 2,4-dinitrotoluene is the CSF for a mixture of 2,4-dinitrotoluene and 2,6-dinitrotoluene.

In addition, no CSFs are provided in IRIS (1996) or HEAST (EPA, 1995a) for the potentially carcinogenic PAHs benz(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, and indeno(1,2,3-cd)pyrene. However, provisional oral and inhalation CSFs have been developed by the EPA-NCEA Superfund Health Risk Technical Support Center and are provided in the latest version of EPA Region III's Risk-Based Concentration Table (EPA, 1995b). According to the methodology used, the toxicity of potentially carcinogenic PAHs can be compared to that of benzo(a)pyrene using Toxicity Equivalent Factors (TEFs) of 0.1 for benz(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene; 0.01 for benzo(k)fluoranthene; and 0.001 for chrysene. Therefore, multiplying the oral and inhalation CSFs for benzo(a)pyrene by the TEFs for the respective PAHs yields the following oral and inhalation CSFs: 0.73 and 0.61 (mg/kg/day)<sup>-1</sup> for benz(a)anthracene, benzo(b)fluoranthene, and indeno(1,2,3-cd)pyrene; 0.073 and 0.061 (mg/kg/day)<sup>-1</sup> for benzo(k)fluoranthene; and 0.0073 and 0.0061 (mg/kg/day)<sup>-1</sup> for chrysene.

The oral and inhalation CSFs for PCE and TCE have been removed from IRIS (1996) and HEAST (EPA, 1995a) pending further evaluation of their carcinogenic potential in humans. The CSF values presented for these chemicals in Table 6-7 are provisional values from EPA-NCEA provided in EPA Region III's Risk-Based Concentration Table (EPA, 1995b).

**Chemicals With No Established RfDs**--Noncarcinogenic effects were evaluated for all of the organic COPCs identified for the HRA, including potentially carcinogenic chemicals. The majority of chemicals detected at QADSY and considered as COPCs have toxicity values developed by EPA.

The oral RfD for TCE and the inhalation RfD for carbon tetrachloride are interim values provided by EPA-NCEA and presented in EPA Region III's Risk-Based Concentration Table (EPA, 1995b).

The oral RfD for vinyl chloride is the chronic minimum risk level (MRL) provided in ATSDR's Toxicological Profile for Vinyl Chloride (1989b). The oral value of 0.0095 mg/kg/day for N-nitrosodi-N-propylamine is the human MRL based on an acute oral MRL for rats of 0.095 mg/kg/day (ATSDR, 1988b) and an uncertainty factor of 10 (acute-to-chronic extrapolation).

For comparative purposes, the oral RfD for the PAH pyrene (0.03 mg/kg/day) was used to evaluate potential noncarcinogenic hazards associated with exposure to the carcinogenic PAHs detected at the site.

With respect to the inorganic COPCs, no RfDs are available for metallic thallium. The oral RfD for thallium chloride (the most toxic thallium salt) is used to evaluate this metal.

#### 6.2.4.4 Uncertainties Related to Toxicity Information

The carcinogens identified at the site were mostly Group B2 and C carcinogens; direct evidence of human carcinogenicity is not available for these compounds. This lack of human evidence introduces an uncertainty, due to inherent physiological differences between humans and experimental animals. CSFs developed by EPA use a nonthreshold dose-response assumption for carcinogenicity, which may not accurately represent the dose-response relationship.

The quantitative uncertainty (uncertainty factor and modifying factor) associated with each toxicity value is listed in Table 6-7. The greater the uncertainty factor/modifying factor, the greater the uncertainty behind applicability of the value to the environmental exposure conditions.

#### 6.2.4.5 Summary of Toxicity Information

Table 6-7 summarizes the toxicity information for all of the COPCs evaluated in the HRA. Table 6-8 presents a description of WoEs for potential carcinogens.

#### 6.2.5 Risk Characterization

The objective of this risk characterization is to integrate information developed in the exposure assessment (Section 6.2.3) and the toxicity assessment (Section 6.2.4) into a complete evaluation of the potential and actual human health risks associated with contaminants at the areas of concern. The HRA evaluates the nature and degree of risk to the potential receptor populations described in Section 6.2.3. Wherever possible, risk estimates are derived for individual source areas as well as for the total contaminant contribution from the site to aid in developing priorities for remedial action planning.

The methods used in this risk characterization are based on those presented in EPA risk assessment guidance for human exposures (EPA, 1989a,b, 1991b,c,d, 1992) and EPA Region III guidance (EPA, 1993a, 1995b). Uncertainties associated with each of the analyses are presented along with relevant calculations. These uncertainties may be attributed to several input factors such as lack of monitoring data, incomplete understanding of the mechanisms involved in contaminant transport, assumptions used in the RA, or lack of toxicological information for a particular contaminant.

##### 6.2.5.1 Methods for Human Risk Characterization

**Carcinogenic Risk--**The potential risks associated with exposure to individual carcinogens are calculated using CSFs from IRIS (1996) and HEAST (EPA, 1995a) as presented in Section 6.2.4. The risk is the chemical intake value multiplied by the CSF.

$$Risk = I * CSF \quad (6-4)$$

Where:

- Risk = probability for an individual developing cancer under the assumed exposure conditions (unitless),  
I = daily chemical intake averaged over a lifetime of 70 years (mg/kg/day), and  
CSF = carcinogenic slope factor, expressed in (mg/kg/day)<sup>-1</sup>.

The formulas and factors used to calculate the intakes are included in Appendix K. The intake values used for different pathways are included in Appendix L. The combined risk from exposure to multiple chemicals at a site is evaluated by addition of resultant risks from different chemicals.

$$Risk_T = \sum Risk_i \quad (6-5)$$

Where: Risk<sub>T</sub> = the sum of individual chemical risks, unitless probability; and  
Risk<sub>i</sub> = the risk estimate for the i<sup>th</sup> chemical.

Risks are also added across the pathways if the multiple exposures are to the same individual [e.g., a person working with the soil onsite could be exposed by both the potential exposure pathways (namely oral and dermal) and, if relevant, inhalation; therefore, the pathways are additive.

$$Risk_{Soil} = Risk_{Pathway_1} + Risk_{Pathway_2} + \dots + Risk_{Pathway_i} \quad (6-6)$$

The site-specific carcinogenic risk estimates were based on the RME concentrations and the exposure factors presented in Section 6.2.3 and Appendices J and K. The potential risks resulting from exposure to the site contaminants are compared with the EPA target risk range. Contaminant concentration levels that present cancer risks that fall within the range of 1 in 10,000 to 1 in 1,000,000 (10<sup>-4</sup> to 10<sup>-6</sup>) are generally considered to be acceptable health risks [40 Code of Federal Regulations (CFR) 300, 430:62]. EPA uses the 10<sup>-4</sup> to 10<sup>-6</sup> risk range as a "target range" within which EPA strives to manage risk as part of Superfund cleanup. Therefore, the risk results for this study are summarized to highlight those individual chemicals and media that exceed the lower bound of the risk range, 10<sup>-6</sup>. The 10<sup>-6</sup> risk level serves as a starting point, or point-of-departure to provide focus on those chemicals that may require further evaluation as part of subsequent studies (i.e., feasibility studies) if the cumulative site risk exceeds 10<sup>-4</sup>. When a cumulative carcinogenic risk to an individual under the assumed exposure conditions at the site exceeds 1 in 10,000 (10<sup>-4</sup>), CERCLA generally requires remedial action at the site (EPA, 1991d).

If the cumulative risk is less than 10<sup>-4</sup>, action generally is not required but may be warranted if a risk-based chemical-specific standard [e.g., maximum contaminant level (MCL)] is



violated, or a risk manager indicates that a lower risk level must be achieved due to site-specific reasons. In addition, remediation may be required due to the presence of unacceptable noncarcinogenic effects or ecological impacts.

**Noncarcinogenic HI**--Noncarcinogenic health risks are estimated by comparing actual or expected exposure levels to acceptable concentrations. This is accomplished by calculating a noncarcinogenic hazard quotient (HQ). An HQ is the ratio of chronic daily intake of the site contaminant and the chronic RfD of the contaminant and is calculated as follows:

$$HQ = \frac{I}{RfD} \quad (6-7)$$

Where:

I = intake of contaminant (mg/kg/day), and  
RfD = reference dose of contaminant (mg/kg/day).

The impact from the presence of multiple chemicals at a site is considered additive of impacts from individual contaminants. Thus, the hazard index (HI) is equal to the sum of the HQs:

$$HI = \frac{I_1}{RfD_1} + \frac{I_2}{RfD_2} + \dots + \frac{I_i}{RfD_i} \quad (6-8)$$

Where:

$I_i$  = intake for the  $i^{\text{th}}$  toxicant (mg/kg/day), and  
 $RfD_i$  = reference dose for the  $i^{\text{th}}$  toxicant (mg/kg/day).

I and RfD are expressed in the same units and represent the same exposure period (i.e., chronic, subchronic, or shorter term). The conclusions are as expressed as "no concern", "possible concern", and "high concern", depending on whether the HQ/HI is <1, 1 to 10, or >10, respectively. In other words, when the HQ/HI exceeds 10, there may be substantial concern for potential health effects. An HQ or HI between 1 and 10 suggests that exposure may reduce the margin of safety inherent in the exposure scenario and may be of possible concern for sensitive individuals. An HQ/HI less than 1 indicates that it is unlikely for even sensitive populations to experience adverse health effects. While any single chemical with an exposure level greater than the toxicity value will cause the HI to exceed unity, for multiple chemicals the HI can also exceed unity due to additivity of multiple chemical HQs.

The HI is estimated for both carcinogens and noncarcinogens to obtain an assessment for the overall potential for noncarcinogenic health effects. The site-specific risk characterization for QADSY is presented in the following sections.

#### 6.2.5.2 Site-Specific Results of Risk Characterization for Current and Future Land Use

Using the risk evaluation methods described previously, the exposure concentrations for the RME risk estimates were obtained for the noncarcinogenic and carcinogenic COPCs identified at the site. The human risk results are presented in Appendix M and are discussed in the following sections. A summary of the human risk results is presented in Table 6-9.

**Current Worker**--The current worker exposure scenario evaluated at QADSY is for a worker exposed infrequently to contaminants in surface soil and vapors in indoor air. Based on the exposure assumptions evaluated, the current potential cumulative cancer risk associated with exposure to soil and air is  $4 \times 10^{-5}$ , which is within the cumulative risk range of  $10^{-4}$  to  $10^{-6}$ . The cumulative HI for noncarcinogenic effects from inhalation of indoor air and exposure to soils is 0.2. These results indicate that the site does not pose adverse health effects or risks to current workers based on the exposure parameters evaluated.

**Future Worker**--The future exposure scenario evaluated at QADSY is for a worker exposed to contaminants in surface soil and vapors in air on a daily basis. Based on the exposure assumptions evaluated, the future potential cumulative cancer risk associated with inhalation of indoor air is  $9 \times 10^{-4}$ , which exceeds the upper limit of permissible cumulative risk range of  $10^{-4}$  (Table 6-9). The COPCs contributing to the excess risk in air are vinyl chloride, 1,1-DCE, carbon tetrachloride, TCE, chloroform, and PCE. The potential increased risk due to exposure to soil is  $2 \times 10^{-5}$ , which is within the acceptable risk range.

For noncarcinogenic effects, the HI associated with future worker inhalation of indoor air is 4, which is within the level of "possible concern" of 1 to 10. The majority (98 percent) of the exceedance is due to inhalation of carbon tetrachloride. The HI for future worker exposure to soil is 0.1, which is less than the target HI of 1.

These risk and HI results indicate that inhalation of site COPCs in indoor air may result in adverse health effects or risks to future workers based on the exposure parameters evaluated. Future worker exposure to site soils, however, is not expected to adversely impact worker health based on the exposure parameters evaluated.

**Future Residential**--The future residential exposure scenario evaluated for QADSY conservatively assumes that a residence is built on the existing property and no remediation occurs at the site. Based on the exposure assumptions evaluated, the future potential cumulative cancer risk associated with residential inhalation of indoor air is  $1 \times 10^{-3}$ , which exceeds the upper limit of permissible cumulative risk range of  $10^{-4}$  (Table 6-9). The COPCs contributing to the excess risk in air are vinyl chloride, 1,1-DCE, carbon tetrachloride, TCE, chloroform, and PCE. The potential increased risk due to exposure to soil is  $7 \times 10^{-5}$ , which is within the acceptable risk range.

For noncarcinogenic effects, the HIs associated with future residential inhalation of indoor air by adults and children are 4 and 22, respectively, which are above the target cumulative HI of 1. The majority (96 to 98 percent) of the exceedance is due to inhalation of carbon

tetrachloride. For child indoor air inhalation, 1,1,1-TCA and 1,1-DCE also contribute to the total HI exceeding 1. While the adult HI is within the range of "possible concern", the child HI is greater than 10 and suggests that inhalation exposure to the modeled indoor air concentrations may result in adverse health effects.

The future residential child soil exposure scenario resulted in an HI of 2 due to dermal contact and incidental ingestion of thallium (Table 6-9). This HI (in the range of 1 to 10) suggests that daily contact and ingestion of site soil by a child may be of "possible concern". The HI calculated for future residential adult exposure to soils is 0.3, which is below the target HI and suggests that exposure of residential adults would not result in adverse health impacts based on the exposure parameters evaluated.

Alteration of the site to support a residential setting is highly unlikely due to the maritime industrial nature of the area. In addition, the site is covered with six to eight inches of gravel (scheduled to be paved in the near future) and the remaining site vicinity is paved, effectively removing the point of exposure. Although residential exposure is evaluated in this HRA, it is done only to provide perspective on worst-case plausible exposures and will not be used as a basis for remedial decisions.

In addition, the concentrations of several IOCs (antimony, arsenic, beryllium, cadmium, chromium, lead, selenium, and thallium), bis(2-ethylhexyl) phthalate, and numerous VOCs (all except chloroform) detected in site groundwater exceed drinking water criteria. However, as discussed in Section 6.2.3.2, groundwater beneath the site is not potable, and MCLs and other drinking water criteria are not considered appropriate for evaluating groundwater chemical concentrations at this site.

#### **6.2.5.3 Summary of Uncertainties Associated with the HRA**

The risk measurements used in Superfund RAs are not full probability estimates of risk but are conditional estimates given a set of assumptions about exposure and toxicity. Therefore, it is important to fully specify the assumptions and uncertainties inherent in the HRA to place the risk estimates in proper perspective (EPA, 1989b). Uncertainty analysis is also essential for an FS.

A qualitative uncertainty analysis of each HRA component is sufficient for most sites (EPA, 1989b). Table 6-10 presents the potential uncertainties inherent in the HRA process. A site-specific discussion of these individual components is summarized in the following sections.

#### **Uncertainties Associated with the COPC Selection**

The data used for this HRA were collected over time and by different contractors using different QA/QC procedures. This sampling variance results in the variation in the analytical methods used and DLs reported.

The possibility exists that a COPC or a toxic metabolite was not identified through the sampling and analytical process or that the results are not an accurate representation of the

concentrations that occur onsite. Another potential source of uncertainty associated with the data set used in this evaluation is that the sampling was conducted over different time periods by different contractors using different approved work plans. Such samples were analyzed using different analytical methods and DLs, which contribute to the uncertainty in the chemicals detected and their concentrations.

Automation of the data evaluation reduces associated uncertainty as DLs are automatically halved and the comparison of the  $UCL_{95}$  to the maximum concentration is automated to reduce human error in making these numerical comparisons.

Another source of uncertainty resulting in overestimates of risk is due to extraneous contamination introduced during sampling or analysis. For example, acetone and methylene chloride were frequently detected and were included as COPCs, although these compounds could be laboratory artifacts and not site-related.

#### **Uncertainty Associated with the Exposure Assessment**

The major uncertainty in the exposure assessment lies in the pathways selected. The exposure pathways chosen for the QADSY are not expected to occur on a regular basis. Most of the risk estimates are based on projections of what may occur in the future. The plans for the site do not include construction of residential units; therefore, future residents at these sites are unlikely.

The exposure concentrations used in the calculation of intakes were  $UCL_{95}$  concentrations found in soil and groundwater. It was conservatively assumed that all areas at a site had concentrations equal to the  $UCL_{95}$  for each contaminant detected at the site. Although this is the accepted method for conservatively estimating exposure concentrations, it is a source of uncertainty. Another source of uncertainty is the use of modeled exposure concentrations due to the absence of monitoring data. As the data were collected by different contractors over time and analyzed for different target compounds, a temporal trend in the data has not been established for this site. Thus, the exposure concentrations could overestimate or underestimate the exposure concentration because a trend in the nature of contamination is not known.

Considerable uncertainty is associated with the quantification of exposure. The exposure factors used most frequently are those default assumptions from EPA sources. When necessary, study-area-specific information is incorporated to reduce the uncertainty. However, for air contaminant concentration and fish contaminant concentration estimations, the parameters used were conservative estimates. For instance, methods to estimate inhalation exposure to volatiles may overestimate intake and risk.

Additional uncertainty comes from the assumption that receptors completely absorb chemicals to which they are exposed. Toxicological effects in humans depend largely on the amount of a chemical that the body actually absorbs. Assuming complete absorption of all chemicals should lead to an over-estimation of potential health risks.

Reduced exposure by any or all routes would be expected if the future worker was not spending the entire exposure time at the contaminated area. Certain individuals may be more sensitive to the adverse effects of contaminant exposure because of poor health, age, or other factors.

### **Uncertainty Associated with the Toxicity Assessment**

A majority of the uncertainty in an HRA is associated with the use of dose-response data that have been generated under experimental laboratory conditions (using non-human mammals) and extrapolating these results for comparison to (i.e., RfD) human exposure under a different environmental exposure scenario. To extrapolate the experimental evidence from animals to humans, a series of uncertainty factors and modifying factors, which have been derived by EPA, are applied. These uncertainty factors and modifying factors are the quantitative uncertainty associated with the value in question and are presented in Table 6-7.

As with the noncarcinogenic dose-response assessment, the carcinogenic dose-response assessment includes the following:

1. Selection of the appropriate data sets;
2. Derivation of estimates at low doses from experimental data at high doses, using an appropriate extrapolation model (extrapolation is ordinarily carried out first by fitting a mathematical model to the observed data and then by extending the model from the observed range down toward risks expected at low exposure) (IRIS, 1995);
3. Selection of an equivalent human dose when animal data sets are used;
4. Introduction of additional assumptions, with corresponding additional uncertainties, for route-to-route extrapolation when only one route has been tested in animals or evaluated in humans.

The level of confidence associated with the CSFs from EPA can be obtained from the literature from which the dose-response studies for the carcinogenic COCs were obtained.

### **Uncertainty Associated with the Risk Characterization**

The uncertainties of the risk characterization include the uncertainties associated with the previous three steps of the HRA process. In most cases, the uncertainties are more than compensated for by inclusion of upperbound exposure concentrations (Section 6.2.3.3), upperbound exposure factors (Section 6.2.3.4), uncertainty factors and modifying factors in developing RfDs and CSFs (Section 6.2.4), and incorporating conservative assumptions in estimated future risks by assuming that contaminant degradation does not occur (Section 6.2.2.2). Incorporation of the factors and variables to account for uncertainty in each step of the HRA process presents a reasonable upperbound estimate of the risks and impacts scenario on which to calculate risks. This procedure ensures the protection of public health, because if the upperbound risk estimate represents an acceptable risk, then there is a high level of confidence that an adverse impact will not occur. Most of the cumulative carcinogenic risk estimated for the site is attributable to Category B2 (probable human)

carcinogens. Thus, it is not known whether these chemicals actually cause cancer in humans, particularly at the low intake levels estimated for the site.

#### 6.2.6 Remedial Goal Objectives (RGOs)

The purpose of the baseline HRA for the QADSY is to assess the potential human health impacts associated with the site-related chemicals under current and future land-use conditions, assuming that no remedial action is occurring at the site. Those chemicals that pose unacceptable health risks in the baseline HRA are further evaluated in the feasibility study (FS) to evaluate a reasonable range of remedial alternatives for migration control and source control measures to reduce site contaminants to acceptable levels. Thus, HRA input is required in the FS to ensure that the overall remediation goal for the site, which is to protect human health and the environment by preventing or reducing contaminant release or migration by implementing appropriate remedial actions, is achieved.

The Superfund Amendments and Reauthorization Act (SARA) requires that remedial actions attain a degree of contaminant cleanup that assures protection of public health and the environment. Thus, in the event that the baseline HRA of a site indicates the need to reduce site COPCs to acceptable health-based levels, RGOs, must be developed. RGOs are chemical-specific concentration goals for individual chemicals for specific medium and land use combinations at CERCLA sites (EPA, 1991b). There are two sources of RGOs: (1) concentrations based on applicable or relevant and appropriate requirements (ARARs) and (2) concentrations based on risk assessment (risk-based concentrations under specific exposure conditions) (EPA, 1991b).

A chemical-specific ARAR may not always be protective if the chemical exists in a mixture; in addition, chemical-specific ARARs have not been established for many chemicals, particularly for chemicals detected in soil. Thus, in the absence of an ARAR or, in instances where an ARAR is not protective, RGOs can be developed based on baseline HRA guidance to ensure that they meet the threshold criteria of (1) protection of human health and the environment, and, (2) compliance with ARARs (EPA, 1991d).

RGOs for QADSY are established based on the most current EPA guidance on the role of the baseline RA in the remedy selection process (EPA, 1991d), as well as guidance regarding the development of RGOs (EPA, 1991b). As stated in EPA guidance (EPA, 1991d) action is generally not warranted at a Superfund site where:

1. The cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than  $10^{-4}$ ,
2. The noncarcinogenic hazard quotient is less than 1,
3. No adverse environmental impacts exist, and
4. ARARs (i.e. MCLs, non-zero MCLGs) are not exceeded.

RGOs may not be required for a COPC in the event that the above four criteria are met. This is consistent with EPA guidance on development of PRGs (EPA, 1991b), which states that

RGOs must be maintained for contaminants in a medium when any of the above listed criteria are exceeded. However, because the risk level for triggering remediation has not been chosen at this time, all chemicals contributing an individual risk  $\geq 1 \times 10^{-6}$  or an HQ  $\geq 0.1$  to a cumulative risk of  $10^{-4}$  or greater or an HI of at least 1, respectively, are included for RGO development.

As discussed in Sec. 6.2.5.2, the site is located in an industrial area, and is intended to remain as such. In addition, the site is covered with six to eight inches of gravel and is scheduled to be paved in the near future, while the remaining site vicinity is paved. While an assessment of residential exposure is performed in this HRA, according to discussions with regulatory agencies responsible for the site, it is done only to provide perspective on worst-case plausible exposures and will not be used as a basis for remedial decisions. Based on EPA regional and site-specific guidance, the four criteria identified above, and the results of the baseline HRA, RGOs are developed for the future worker and future residential exposure scenarios, only.

#### 6.2.6.1 Soil RGOs

Current worker and future worker exposures to soil are not expected to result in unacceptable risks ( $> 10^{-4}$ ) or HIs ( $> 1$ ); therefore, no RGOs for carcinogenic or noncarcinogenic effects from soil exposure are developed.

#### 6.2.6.2 Groundwater RGOs Based on Inhalation of Vapors in Indoor Air

**RGOs for Carcinogenic Effects**--The results of the risk characterization at QADSY indicate that cumulative risks associated with future worker exposures to vapors from groundwater exceed EPA's upperbound cumulative risk level of  $10^{-4}$ . Thus, all chemicals contributing an individual risk of  $1 \times 10^{-6}$  or greater were included for RGO development for risk management decision-making (Table 6-11).

Because the RGO for groundwater is based on excess risks associated with inhalation exposure to vapors emitted from groundwater, the RGOs for potential carcinogens were developed by first calculating the target air concentration followed by calculating the target groundwater concentration associated with the target air concentration. The target air concentration was determined using ratios as follows:

$$C_{air,target} = \frac{C_{air,site} * Risk_{air,target}}{Risk_{air,site}} \quad (6-9)$$

Where:

- $C_{air,target}$  = chemical-specific RGO for air ( $\text{mg}/\text{m}^3$ ),
- $Risk_{air,target}$  = chemical-specific target risk for air (unitless),
- $C_{air,site}$  = chemical-specific exposure concentration in air at the site ( $\text{mg}/\text{m}^3$ ), and
- $Risk_{air,site}$  = chemical-specific site risk associated with air (unitless).

Using the target air concentration calculated above, the target groundwater concentration can be determined by the ratio of the target exposure concentrations in air and groundwater to the ratio of the site-specific exposure concentrations in air and groundwater. Solving for the groundwater target concentration, the equation is:

$$C_{gw\_target} = \frac{C_{gw\_site} * C_{air\_target}}{C_{air\_site}} \quad (6-10)$$

Where:

- $C_{gw\_target}$  = chemical-specific RGO for groundwater =  $RGO_{gw}$  (mg/L),
- $C_{gw\_site}$  = exposure concentration in site groundwater (mg/L),
- $C_{air\_target}$  = target air concentration at the site (mg/m<sup>3</sup>), and
- $C_{air\_site}$  = exposure concentration in air at the site (mg/m<sup>3</sup>).

Substituting Equation 6-10 into Equation 6-9 yields the following formula for calculating groundwater RGOs:

$$RGO_{gw\_canc} = \frac{C_{gw\_site} * Risk_{air\_target}}{Risk_{air\_site}} \quad (6-11)$$

For example, the carcinogenic groundwater RGO for future worker exposure to 1,1-DCE would be calculated as follows:

$$RGO_{gw\_canc} = \frac{0.14 * 1 \times 10^{-6}}{3.7 \times 10^{-4}} = 3.8 \times 10^{-4} \text{ mg/L} \quad (6-12)$$

**RGOs for Noncarcinogenic Effects**--The results of the risk characterization at QADSY indicate that cumulative HIs associated with future worker and future residential exposures to vapors from groundwater exceed EPA's target HI of 1. Thus, all chemicals contributing an individual HQ of 0.1 or greater were included for RGO development for risk management decision-making (Table 6-11).

To determine the target groundwater concentration based on noncarcinogenic effects, the target HI of 1 is substituted for target risk in Equation 6-12 and the site-specific HI is substituted for the site-specific risk as follows:



$$RGO_{gw_{noncarc}} = \frac{C_{gw_{site}} * HI_{air_{target}}}{HI_{air_{site}}} \quad (6-13)$$

For example, the noncarcinogenic groundwater RGO for future residential child exposure to carbon tetrachloride would be calculated as follows:

$$RGO_{gw_{noncarc}} = \frac{0.12 * 1}{21} = 0.0057 \text{ mg/L} \quad (6-14)$$

### 6.3 Ecological Risk Assessment (ERA)

#### 6.3.1 Identification of COPCs

COPCs are the site-related chemicals that may pose health concerns to environmental receptors. The data considered in the ERA (the same data considered for the HRA) were taken from ESE and Baker Environmental sampling events (1990-1995) and sampling events from a previous contractor (Malcolm Pirnie, 1983-1986). Chemicals detected at QADSY include volatile organic chemicals (VOCs), semi-volatile organic chemicals (SVOCs), inorganic chemicals (IOCs), and pesticides in soil, and VOCs, SVOCs, and IOCs in groundwater. While no direct exposure to groundwater is expected, groundwater concentrations will be used to model surface water concentrations for potential exposure of aquatic life and piscivorous (fish-eating) birds.

##### 6.3.1.1 Data Evaluation

The first step in the COPC selection process is to determine which data will be evaluated in the ERA. The most recent and/or reliable data were used in the COPC selection process and in the calculation of exposure concentrations. These data are the same data used in the HRA.

**Soil--**For soil, data from the five samples collected in 1995 were added to the previous soil data as the newer samples were collected from different locations and were analyzed for all priority pollutants. The previous data used includes Malcolm Pirnie data for IOCs, pesticides, and miscellaneous SVOCs. During the previous ESE investigation, the majority of the SVOC results were below the limits of detection. The DLs reported for the SVOC data were relatively high, limiting the usefulness of this data set. For this reason, the previous ESE SVOC data were disregarded, and the SVOC data from the Malcolm Pirnie report were used. Soil VOC concentrations were based solely on ESE and Baker Environmental data because this data exhibited acceptable DLs.

**Groundwater--**The groundwater data available for the site include IOCs, an SVOC, and VOCs in shallow and deep aquifers. Previous samples from the wells located directly on the storage yard were sampled for the full complement of VOCs and IOCs, while the samples collected from locations to the west of the storage yard were analyzed for TCE, PCE, and

1,2-DCA. The primary concern with respect to evaluating groundwater data is the potential for groundwater contaminants to migrate into surface water (IOCs and VOCs) and sediment (IOCs) of the Elizabeth River.

Different data sets were used to evaluate the shoreline concentrations of VOCs and IOCs. The method used for the VOC concentrations was based upon the TCE and PCE plumes in groundwater that have been well delineated at the site and are assumed to represent the area with the highest VOC contamination. The wells included in the evaluation of the VOC concentrations in groundwater were the following: SW-1-1, SW-1-1FD, SW-1-2, SW-2-1, SW-2-2, SW-6-1, SW-6-2, SW-4-1, SW-4-2, DW-1, GW-1-1, GW-1-2.

The TCE and PCE concentrations at the shoreline were well defined; therefore, a subset of the shoreline wells was used to evaluate these two contaminants. The subset of wells that was used for TCE and PCE shoreline groundwater concentrations included: SW-9, SW-10, DW-5, DW-6, HP-10, HP-11, HP-13, HP-15, and HP-17.

The IOCs groundwater data were taken as a whole because a subset of the data may not be representative of the IOCs at the shoreline. Since the source of the IOCs may not be co-located with the VOCs and the migration of IOC contamination in groundwater may be totally independent of VOC migration, all groundwater data were used to evaluate IOC data.

Eight groundwater samples were collected in 1995 and analyzed for full-scan priority pollutants. The previous data from the eight wells sampled in 1995 were replaced with the new data for those wells. Previous data from the wells not sampled in 1995 were kept in the groundwater data set.

**Data Qualifiers**--Based on EPA guidance (1989b), groundwater and soil data flagged with a "J" (estimated concentration) or "L" (result may be biased low) were used the same way as data that do not have these qualifiers to ensure that a site-related chemical was not overlooked. Groundwater organic data and soil data qualified with a "B" (chemical found in associated blank) were not included in the data set to be evaluated. However, groundwater inorganic data flagged with a "B" was included because in this set of data "B" signifies that the chemical was detected above the instrument DL but below the required method DL. Although the detection is questionable, it has been considered.

#### **6.3.1.2 COPC Selection**

After the appropriate data set to be evaluated is determined, the COPC list is compiled. Unlike for HRA, no methodology has been established by EPA Region III for screening potential COPCs for ecological exposure. As a general screening tool, inorganic chemicals (1) not detected significantly above background or (2) considered essential nutrients are removed from the list of COPCs.

As discussed in the COPC selection for the HRA (Section 6.2.1.2), the presence of IOCs in onsite samples may or may not be associated with site activities. To determine if IOCs are

site-related, the maximum concentrations of inorganic chemicals detected in site samples are compared to the average concentrations in background samples. IOCs were included as COPCs if the maximum concentrations detected onsite are greater than two times the average background concentrations.

Comparisons of the detected concentrations of IOCs in site samples to background concentrations are presented in Table 6-2. The maximum concentrations of aluminum, antimony, cadmium, chromium, mercury, nickel, and silver in site samples did not exceed 2 times the background concentrations of these IOCs; therefore, these IOCs were removed from the list of soil COPCs in the ERA.

As discussed in the HRA (Section 6.2.1.2), site-specific background samples were not collected at QADSY. Regional background soil concentrations are available for many IOCs; however, since site "soils" are actually sediments dredged from a nearby water body, comparison of site concentrations to regional background levels is not appropriate. Baker Environmental, who performed the latest round of soil sampling and analysis at the QADSY, collected background soil borings during their evaluation of the Building LP-20 site, another study area at Norfolk Naval Base. With acceptance from the Navy and Baker Environmental, the results of these background soil samples were used to evaluate the QADSY soil data.

Also, as calcium, magnesium, potassium, and sodium are essential nutrients, exhibit low toxicity, and do not have any established toxicity benchmarks, these IOCs have been removed from the list of soil COPCs. While iron is also considered an essential nutrient, a toxicity benchmark is available for this IOC (Section 6.3.4), and iron has been included on the soil COPC list. The final list of soil COPCs for the ERA is presented in Table 6-12.

### **6.3.2 Environmental Fate and Transport**

The fate and transport processes for the ERA COPCs are the same as those for the HRA and discussed in Section 6.2.2.

### **6.3.3 Exposure Assessment**

The exposure assessment uses information obtained from the site characterization and the environmental fate and transport analysis to identify significant complete exposure pathways and to estimate actual or potential COPC concentrations for each exposure pathway. Behavioral or physiological factors influencing exposure frequency and exposure levels are then presented in a series of exposure scenarios as a basis for quantifying chemical intake levels by receptor populations for each significant completed exposure pathway. Results of the exposure assessment are used in conjunction with the information summarized in the toxicity assessment to determine the potential site-related health risks to ecological receptors.

#### **6.3.3.1 Exposure Pathways**

An exposure pathway is the route over which a chemical or physical agent migrates from a contaminant source to an exposed population or individual (receptor) and also describes a unique mechanism by which the receptor may be potentially exposed to chemicals or physical

agents at or originating from the site. For an exposure pathway to be complete, the following four elements must be present:

- A source or release from a source (e.g., material leaking from a drum);
- A likely environmental migration route (e.g., movement of a chemical through soil to groundwater and into surface water);
- An exposure point where receptors may come in contact with site-related chemical or physical agents (e.g., local creek); and
- A route by which potential receptors may be exposed to a site-related chemical or physical agent (e.g., dermal contact with water).

If any of these four elements is not present, the exposure pathway is considered incomplete and is not expected to contribute to the total exposure from the study area. A screening of each exposure pathway element was conducted to identify significant completed exposure pathways. This screening ensures that the risk characterization focuses only on the media and completed exposure pathways and eliminates from further consideration those pathways that are incomplete. Each of the four components of the potentially completed exposure pathways is discussed in the following sections. The exposure equations and factors used for the HRA are described in Appendix K.

**Exposure to Soil**--Animals may be present in or on the soil and, depending on their physiological capabilities and behavior, may migrate or burrow between various contaminated soil layers. Potential exposure pathways for animals from contaminated soils may include the following:

- Dermal contact by burrowing animals;
- Ingestion of contaminated soils;
- Inhalation of contaminated wind-borne dusts;
- Dermal exposure from contaminated soil particles adhering to skin, fur, or feathers;
- Inadvertent consumption of soils via digging and burrowing activities;
- Ingestion of animals or plants on which contaminated soils adhere; and
- Ingestion of contaminated prey items (plants and animals) by resident and nonresident consumers. This pathway would be most applicable to predatory animals for COPCs that are significant bioaccumulators.

Terrestrial ecological receptors may be exposed to COPCs in soil via the dermal, inhalation, and oral routes. The methods for the estimation of dermal absorption of contaminants into animal tissue and inhalation of vapors and airborne particles are currently under development for use in risk assessment; therefore, these pathways will not be evaluated in this ERA. The primary exposure pathway to soil chemicals for terrestrial receptors is direct ingestion of soil during feeding, burrowing, grooming, etc. Portions of the QADSY are paved. The remaining area is covered with six to eight inches of gravel and is scheduled to be paved. In addition, terrestrial animals would not be expected to frequent and have not been observed at the QADSY as the area is not located near any habitat that would provide adequate food or

shelter for terrestrial animals. Therefore, exposure of terrestrial organisms to soil is not considered complete for any quantifiable pathways and is not evaluated further in the ERA.

**Exposure to Aquatic Media and Organisms**--Piscivorous avian species are expected to be exposed to COPCs through their exposure to surface water and contaminated fish. The most significant exposure pathway was assumed to be the ingestion of potentially contaminated fish. In addition, there are no published EPA methodologies for the evaluation of dermal and inhalation uptake in avian species from surface waters. The only pathway evaluated for the wading bird at this site is the ingestion of potentially contaminated fish. This pathway is expected to account for the majority of COPC uptake in the avian indicator species.

Aquatic species inhabiting the Elizabeth River would be exposed to surface water constituents via uptake across cellular membranes (algae) and digestive and/or gill surfaces (invertebrates). In addition, benthic-dwelling organisms would have constant exposure to chemicals present in Elizabeth River sediment.

#### 6.3.3.2 Receptor Identification

The QADSY is located in an industrial area with limited vegetative cover, which would provide habitat for terrestrial wildlife. Potential exposure of terrestrial animals to contaminated surficial soils was evaluated in Sec. 6.3.3.1 and, due to the lack of exposed soil, was found to be incomplete. Therefore, no terrestrial receptors are considered applicable at the QADSY.

To evaluate potential bioaccumulative effects of site contaminants on surface water organisms, one species of wading bird, the great blue heron, is found in Mid-Atlantic habitats and was chosen as the indicator avian species for this ERA. The great blue heron (*Ardea herodias*) is the only species of wading bird that is found during the winter in the northern parts of the Atlantic coast [U.S. Fish and Wildlife Service (USFWS, 1984)]. The great blue heron is one of the larger wading birds, eating fish as small as minnows or as large as 20 to 25 centimeters (cm) in length. Other items in the great blue heron's diet include crayfish, snails, frogs, lizards, and snakes (USFWS, 1984). The potential for bioaccumulation of IOC's into fish in the Elizabeth River and the subsequent ingestion of these fish by the heron is evaluated in the ERA.

#### 6.3.3.3 Exposure Concentrations

Exposure concentrations are the contaminant concentrations that a receptor may contact at a site. Exposure concentrations are the lesser of the maximum detected concentration and the upper 95th confidence limit of the mean (UCL<sub>95</sub>). This procedure is in accordance with RAGS (EPA, 1989b), which states that if there is great variability in measured concentration values, the UCL<sub>95</sub> will be high, and conceivably could be above the maximum detected value. As a result, in these cases EPA recommends that the maximum detected value be used to estimate exposure concentrations (EPA, 1989b). Therefore, in accordance with RAGS, the exposure concentrations that are used in risk characterization are the lowest of the maximum and UCL<sub>95</sub> values.

For those constituents with concentrations below DLs, one-half of the DL ( $\frac{1}{2}$ DL) was used in the calculation. Because the  $UCL_{95}$  calculation uses values for undetected constituents that are equal to  $\frac{1}{2}$ DL, the calculated  $UCL_{95}$  can be significantly affected by samples where matrix interferences have resulted in sample dilution and significantly elevated DLs have been reported. In some instances, these elevated DLs result in a  $UCL_{95}$  exceeding the maximum concentration of the constituent detected. In these cases, the maximum detected concentration instead of the  $UCL_{95}$  was used for quantifying health risks (Appendix J).

The data used in the ERA (the same as used in the HRA) were taken from ESE sampling events (1990-1995) and sampling events from the previous contractor (Malcolm Pirnie, 1983-1986). The most recent and/or validated data were used in the calculation of the exposure concentrations for the ERA. The following paragraphs explain the methodology used for calculating exposure concentrations and also what data gaps were found during the data evaluation process. A discussion as to what steps were taken to assure the highest possible integrity of the data used in the risk calculations is also included in this section.

**Groundwater Exposure Concentrations**--Groundwater exposure concentrations for the ERA were calculated using the same methodology as for the HRA. The primary ecological concern for groundwater contamination is the potential for groundwater contaminants to migrate into surface water. A summary of the groundwater exposure concentrations is presented in Appendix J, Table J-2. A listing of the samples used to calculate the groundwater exposure concentrations is presented in Appendix J, Table J-3.

**Surface Water Exposure Concentrations**--Groundwater affected by site-related contaminants discharges to the Elizabeth River at Hampton Roads. The Elizabeth River is a tidal inlet with little freshwater input. Hampton Roads is the mouth of the James River Estuary. The James River estuary is classified as a partially mixed estuary (EPA, 1985), but appears to be relatively well-mixed at Hampton roads, where surface salinity averages 17 ppt while bottom salinity averages 20 ppt (Stroup, 1963). Tidal currents through the Hampton Roads are strong, with peak flood and ebb tidal currents approximately equal at 0.75 and 0.79 m/sec, respectively (Browne, 1988). These currents would provide for rapid mixing of site-related contaminants through the water column, as well as effective lateral dispersion. The tidal excursion (distance water flows during a tidal cycle) is approximately 5 miles. According to either of two methods recommended by EPA (1985), conditions at Hampton Roads are indicative of a well-mixed estuary. These factors indicate effective and rapid mixing of contaminants through the full cross-sectional area of Hampton Roads.

Under these conditions, the concentration of site-related contaminants in the estuary can be estimated using equation VI-26 of EPA (1985):

$$C_i = \frac{Q_p * f_i}{R} \quad (6-15)$$

Where:

- $C_i$  = the average concentration in the estuary at the point of discharge ( $\mu\text{g/L}$ ),  
 $Q_p$  = the rate of chemical discharge ( $\mu\text{g/tidal cycle}$ ),  
 $f_i$  = the fraction of fresh water at segment  $i$  (dimensionless), and  
 $R$  = the river discharge rate ( $\text{L/tidal cycle}$ ).

The input parameters were estimated as follows:

Rate of chemical discharge,  $Q_p$ : The rate of chemical discharge,  $Q_p$ , was estimated by multiplying the exposure concentration in groundwater discharging to surface water,  $C_{gw}$ , by the flow rate of contaminated groundwater,  $Q_{gw}$ . The latter was estimated by:

$$Q_{gw} = \frac{K * i * A * 28.3}{TPD} = 6,700 \text{ L/tidal cycle} \quad (6-16)$$

Where:

- $K$  = the hydraulic conductivity (11 ft/day),  
 $i$  = the hydraulic gradient (0.0013),  
 $A$  = the cross-sectional area through which contaminated groundwater flows at the shoreline (1,100 ft x 30 ft = 33,000 ft<sup>2</sup>),  
 $TPD$  = the number of tidal cycles per day (2), and  
 $28.3$  = a conversion factor from ft<sup>3</sup> to liters.

$$\therefore Q_p = C_{gw} (\mu\text{g/L}) * 6,700 (\text{L/tidal cycle}) \quad (6-17)$$

Fraction of fresh water,  $f_i$ : The fraction of fresh water at Hampton Roads is given by equation VI-9 of EPA (1985):

$$f_i = \frac{S_s - S_i}{S_s} = 0.46 \quad (6-18)$$

Where:

- $S_s$  = the salinity of local sea water (35 ppt), and  
 $S_i$  = the salinity at the point of discharge (18.9 ppt, NOAA).

River discharge rate, R: The freshwater discharge of the James River at Hampton Roads was estimated to be approximately 10,500 ft<sup>3</sup>/sec using data from several upstream gaging stations (USGS, 1985). Over a twelve hour tidal cycle, that flow rate equals  $1.3 \times 10^{10}$  (L/tidal cycle).

Applying these values, the concentration in the estuary at Hampton Roads would be estimated as:

$$C_i = \frac{C_{gw} (\mu g/L) * 6,700 (L/tidal\ cycle) * 0.46}{1.3 \times 10^{10}} = 2.37 \times 10^{-7} * C_{gw} (\mu g/L) \quad (6-19)$$

In other words, concentrations would be diluted by approximately 4 million to one upon discharge to the estuary. Surface water exposure concentrations are presented in Table 6-14.

**Fish Exposure Concentrations--**To evaluate potential impacts to great blue heron that may ingest fish caught near the site, modelled surface water exposure concentrations were multiplied by chemical-specific bioconcentration factors (BCFs) to yield an estimated COPC concentration in fish. BCFs and resulting fish tissue concentrations for the surface water COPCs are presented in Table 6-14.

**Sediment Exposure Concentrations--**The sediment toxicity evaluation was limited to the evaluation of IOC. VOCs were not modelled into sediment because they do not typically accumulate in this medium. Because pesticides were not detected in groundwater, this class of chemicals was not modelled into sediment.

Groundwater IOC exposure concentrations were used to estimate the sediment concentrations adjacent to the site. Sediment concentrations of IOCs were estimated by multiplying the groundwater exposure concentration by an adsorption coefficient,  $K_d$  (mL/g), appropriate for each IOC under the environmental conditions existing in the sediments of the Elizabeth River.

A literature search was conducted to locate  $K_d$ s for arsenic and lead that would be appropriate for the environmental conditions at the site. Based on the collected analytical data and the literature search, the conditions that were assumed reasonable for the site are: pH = 7.4, moderately oxidizing, % organic matter = 30%, 12 - 16 ‰ salinity, and temperature of 15-20 °C. The range of reported analytical concentrations is < 1 to 5 µM for arsenic, and 1 to 3 µM for lead. Under these conditions and given data, the following values were the most relevant values reported:

Arsenic:  $K_d = 1,500$  mL/g  
Lead:  $K_d = 6,200$  mL/g

The above values were then adjusted to the salinity (12-16 ‰) observed in the Elizabeth River. The adjustment was made according to the study of Gupta and Chen (1978) who



showed that the adsorption coefficients of IOC's decreased by 50 to 85 percent from distilled water to 10-fold diluted seawater and plain seawater. In this study, a 70-percent decrease was assumed for the  $K_d$ 's of arsenic and lead. Thus, the final values of adsorption constants are the following:

$$\begin{aligned}\text{Arsenic: } K_d &= 450 \text{ mL/g} \\ \text{Lead: } K_d &= 1,860 \text{ mL/g}\end{aligned}$$

The above values are about 2 to 2½ times higher than those recommended as default values for agricultural soils by Baes *et al.* (1984; arsenic = 200 mL/g and lead = 900 mL/g). Surface water sediment appear to have generally a higher adsorptive capacity for IOC's than soils have under similar or comparable environmental conditions. Based on this investigation targeted on arsenic and lead, the  $K_d$  value for other IOC's was assumed to be 2 times the values reported by Baes *et al.* (1984). The  $K_d$  values used for each IOC and the associated sediment exposure concentrations are presented in Table 6-23.

Two onsite samples that have been described as drainage samples (samples had a consistency similar to sediment and were collected from a sewer pipe beneath a drop vent) were analyzed for IOC's and pesticides. Because the ditches drain wide-range areas, the samples were not considered to be representative of site contamination, and therefore, were not used in the ERA. The Malcolm Pirnie data were used for the calculation of IOC, SVOC, and pesticide soil exposure concentrations.

#### 6.3.3.4 Intake Estimates

The basic intake formula for ecological exposure is identical to the formula for human intake (Equation 6-3) presented in Section 6.2.3.4 with the "CR" or "IR" term given in units of kg/day, the "C" term expressed in mg/kg, and the "ED" term expressed in years.

$$I = \frac{C * IR * \text{soil fraction} * FI * EF * ED}{BW * AT} \quad (6-20)$$

Because the actual exposure (including food type, duration, and concentration) for the great blue heron at the site is unknown, an exposure pathway was developed to estimate exposure doses that could then be compared with ecotoxicity benchmark values. Therefore, the exposure of the great blue heron to fish is evaluated with a conservative chemical intake versus toxicity reference value (TRV) methodology.

Most ecotoxicity benchmarks for vertebrates are based on doses administered in feed and are reported as a dose per kilogram of body weight. For the great blue heron (*Ardea herodias*), an intake scenario was developed that assumed a 70 percent of the daily food ration was fish and that only 10 percent of the fish ingested came from the contaminated area. Intake parameters for the heron are presented in Table 6-14 and are described in the following paragraph. Surface water exposure concentrations were multiplied by a BCF to yield a COPC.

concentration in fish (Table 6-15). The fish intake values for the heron (Table 6-14) were multiplied by the chemical exposure concentrations in fish (Table 6-15) to yield the receptor-specific chemical intakes presented in Table 6-15. The intake equation for the heron is as follows:

$$I = \frac{Cf * IRf * DFf * FIf * EF * ED}{BW * AT} \quad (6-21)$$

Where:

- I = intake, the amount of chemical at the exchange boundary (mg/kg/day);
- Cf = chemical concentration in fish, the concentration of a chemical that may be contacted over the exposure period (mg/kg);
- IRf = fish intake rate, the amount of fish ingested per unit time (kg/day);
- DFf = fraction of the total diet that is fish (unitless);
- FIf = fraction of fish ingested from contaminated area (unitless);
- EF = exposure frequency (days/year);
- ED = exposure duration (years);
- BW = body weight, the average body weight of the exposed individual (kg); and
- AT = averaging time, period over which exposure is averaged (days).

The pertinent exposure factors which are used to estimate the intake for the great blue heron are as follows:

- Food intake rate = 396 grams/day (Stalmaster, 1987)
- Fraction of diet consisting of fish = 0.7 (assumed value; based on bald eagle)
- Percentage of diet obtained from affected area = 0.1 (assumed)
- Mean natural life-span = 30 years [based on bald eagle; best estimate since wild birds die younger than captive birds, which can live to 50 years (Stalmaster, 1987)]
- Average body weight = 2.2 kilograms (EPA, 1993b)

Table 6-13 summarizes the methodologies used to evaluate the potential ecological impacts of surface water and sediment contamination, while a summary of the intake parameters for the great blue heron is presented in Table 6-14.

### 6.3.4 Toxicity Assessment

#### 6.3.4.1 Developing Toxicity Reference Values (TRVs)

Risks to ecological receptors are quantitatively evaluated by comparing the chemical intake (for terrestrial receptors) to a TRV for that chemical in the specific receptor. TRVs are derived from unadjusted ecotoxicity benchmarks using the following equation:

$$TRV = \frac{\text{Ecotoxicity Benchmark}}{\text{Applicable Uncertainty Factors}} \quad (6-22)$$

Selected ecotoxicity benchmarks for the surface water COPCs at QADSY were obtained from the available literature and are presented in Table 6-17. Ecotoxicity benchmarks were chosen based on the following considerations:

- Including acute and chronic effects,
- Choosing results of tests using organisms as closely related taxonomically to representative receptors as possible,
- Choosing tests with ecologically relevant endpoints, and
- Choosing tests conducted with an ecologically relevant exposure pathway.

The preferred value sought was a chronic no-observed-adverse-effect level (NOAEL) in the indicator species or related organism. For chemicals with no available chronic NOAEL, other values [e.g., a lowest-observed-adverse-effect level (LOAEL) or the dose/concentration lethal to 50 percent of a study population ( $LD_{50}/LC_{50}$ )] were used to derive a TRV. In the absence of U.S. Navy guidance on the evaluation of ecotoxicity data, the ecotoxicity benchmarks were adjusted to account for extrapolation uncertainties according to guidance provided by the U.S. Army (USA, 1994). The Army's methodology for applying uncertainty factors to ecotoxicity benchmark values is presented in Figure 6-1.

#### 6.3.4.2 TRVS for Terrestrial Receptors

As discussed in Section 6.3.3.1, the great blue heron (*Ardea herodias*) was evaluated for ingestion of fish that may bioconcentrate contaminants from surface water. Potential ecotoxicity for this species is evaluated by comparing the intake of biota-borne chemicals during feeding to the species-specific TRVs presented in Tables 6-17.

Due to the lack of data for heron, ecotoxicity benchmarks for the mouse and rat were predominantly used for the COPCs modeled into Elizabeth River surface water at QADSY. The following avian values were used for the surface water COPCs: an acute  $LD_{50}$  for arsenic and a chronic LD for selenium in mallard ducks (*Anas platyrhynchos*); an acute NOAEL for chromium in the black duck (*Anas rubripes*); an unknown chronic value for lead in the American kestrel (*Falco sparverius*); a chronic LOEL for cadmium and an acute  $LD_{50}$  for mercury in Japanese quail (*Coturnix coturnix japonica*); an acute  $LC_{50}$  for copper in an unknown species of pheasant; acute  $LC_{50}$ s for acetone in Japanese quail (*Coturnix coturnix japonica*) and ring-necked pheasant (*Phasianus colchicus*); and acute  $LC_{50}$ s for thallium in unspecified birds.

#### 6.3.4.3 TRVS for Aquatic Receptors Inhabiting Surface Water

Aquatic receptors are continually in contact with the contaminated medium. As presented in Section 6.3.3, groundwater contaminants are assumed to be discharging to surface water adjacent to the site, resulting in potential bioaccumulation of certain contaminants in fish

tissue and potential exposure to aquatic organisms. Instead of using receptor-specific TRVs, modeled surface water contaminant concentrations were compared to chronic Federal and State ambient water quality criteria. Also, measured onsite groundwater concentrations were compared to acute water quality criteria to evaluate a worst-case scenario of toxicological effects at the groundwater-surface water interface. The level of contamination at the point of discharge is assumed to be equivalent to the level of contamination found in onsite groundwater. This assumption is considered very conservative, as it does not consider physical processes such as dilution, attenuation, or volatilization.

#### **6.3.4.4 TRVS for Aquatic Receptors Inhabiting Sediment**

Similar to surface water receptors, organisms living in sediment are continually in contact with the contaminated medium. Instead of using receptor-specific TRVs, potential impacts to organisms inhabiting river sediments near the site were evaluated using the National Oceanic and Atmospheric Administration (NOAA) sediment benchmarks for LOAELs in marine organisms (1990). Sediment concentrations modelled from the groundwater concentrations at the groundwater-surface water interface were compared to the NOAA values.

#### **6.3.4.5 Uncertainties Related to Toxicity Information**

The quantitative uncertainty (UF) associated with each ecological TRV is listed in Table 6-17. Ecotoxicity data are not available for most nonhuman representative receptors, and some laboratory data do not evaluate ecologically relevant endpoints. Extrapolating from these tests, and among taxa, or the absence of test data contributes to uncertainty. The greater the UF, the greater the uncertainty behind applicability of the value to the indicator species or environmental exposure conditions.

#### **6.3.5 Risk Characterization**

The objective of this risk characterization is to integrate information developed in the exposure assessment (Section 6.3.3) and the toxicity assessment (Section 6.3.4) into a complete evaluation of the potential worst-case ecological health risks associated with contaminants at QADSY. The ERA evaluates the nature and degree of risk to potential receptor populations described in Section 6.3.3. Wherever possible, risk estimates are derived for individual source areas as well as for the total contaminant contribution from the site to aid in developing priorities for remedial action planning.

The methods used in this risk characterization are based on those presented in risk assessment guidance for ecological exposures and assessments (EPA, 1986c, 1988b, 1989c, 1993b) and ECO Updates (issued intermittently by EPA to supplement RAGS). Uncertainties associated with each of the analyses are presented along with relevant calculations. These uncertainties may be attributed to several input factors such as lack of monitoring data, incomplete understanding of the mechanisms involved in contaminant transport, assumptions used in the ERA, or lack of toxicological information for a particular contaminant or receptor.

### 6.3.5.1 Methods for Ecological Risk Evaluation

#### Terrestrial Receptors

The evaluation of potential health risks posed to wildlife is performed in a similar manner as the evaluation of health risks to humans. The main difference between evaluating ecological versus human health risks is that intra-species differences may significantly affect the amount that an animal ingests per body weight or the sensitivity of a species to adverse health effects. To evaluate potential risks to terrestrial receptors, the chemical intakes for a particular indicator species (Section 6.3.3.4) are compared to chemical-specific TRVs derived for that species (Section 6.3.4.2). The ratio of chemical intake to TRV is known as the ecotoxicity quotient (EQ) and is calculated as follows:

$$EQ = \frac{\text{Chemical Intake}}{TRV} \quad (6-23)$$

Chemical intakes and TRVs are expressed in the same units. EQs less than 1 suggest that the benchmark effect is unlikely to occur in the individual; EQs greater than or equal to 1 require further evaluation. Although these EQs may indicate some potential for adverse effects to individuals, at this point, the potential for adverse effects to populations or ecosystems is qualified. Although the EQ method does not provide an estimate of uncertainty and is not an estimation of risk, it is commonly used for screening the potential for ecological effects from exposure to hazardous chemicals (EPA, 1988b).

Great Blue Heron--Diluted surface water concentrations were used to estimate the concentration of contaminants in fish. Health risks to a great blue heron ingesting fish from the river are estimated by comparing estimated chemical intakes (from fish ingestion) to TRVs to produce an EQ (see Equation 6-23). An EQ equal to or exceeding unity ( $\geq 1$ ) suggests that the potential for adverse health effects may exist and indicates that further evaluation of the ecological exposure scenario should be performed. An EQ less than 1 indicates that it is unlikely for even sensitive populations to experience adverse health effects.

#### Aquatic Receptors

Table 6-13 summarizes the methodologies used to evaluate the potential ecological impacts of surface water and sediment contamination.

Surface Water Receptors--As presented in Section 6.3.3.3, groundwater contaminants are assumed to be discharging to surface water adjacent to the site, resulting in potential bioaccumulation of certain contaminants in fish tissue and potential exposure to aquatic organisms. Exposure of potential surface water receptors to site contaminants was evaluated using two methods. First, onsite groundwater concentrations were compared to acute Federal Ambient Water Quality Criteria (AWQCs) and State of Virginia Water Quality Standards (WQSS) to evaluate a worst-case scenario of toxicological effects at the groundwater-surface water interface. The level of contamination at the point of discharge is assumed to be

equivalent to the level of contamination found in onsite groundwater. This assumption is considered very conservative, as it does not consider physical processes such as dilution, attenuation, or volatilization. A ratio greater than one indicates that the potential may exist for adverse effects to occur in an organism exposed to chemical concentrations at the groundwater-surface water interface.

Second, surface water contaminant concentrations that may be found in the open river were modeled from onsite groundwater concentrations using a dilution factor. These modeled concentrations were compared to chronic Federal AWQCs and State WQs to evaluate the potential exposure of aquatic organisms in the area. A ratio greater than one indicates that the potential may exist for adverse effects to occur in an organism exposed to diluted chemical concentrations in the river.

Benthic Organisms--Potential impacts to organisms inhabiting river sediments near the site are evaluated using the NOAA (1990) sediment benchmarks for LOAELs in aquatic organisms. Sediment concentrations modelled from the groundwater concentrations at the groundwater-surface water interface were compared to the NOAA values. A ratio greater than one indicates that the potential may exist for adverse effects in organisms exposed to sediments with the modelled chemical concentration.

#### **6.3.5.2 Site-Specific Ecological Risk Characterization**

Summaries of the potential risks associated with exposure of 1) great blue heron to fish inhabiting surface water near the site, 2) aquatic organisms to area surface water, and 3) benthic organisms to sediments near the site are presented in Tables 6-18, 6-19, and 6-20, respectively.

##### **Great Blue Heron**

A summary of the potential risks associated with exposure of great blue heron to site contaminants due to ingestion of fish is presented in Table 6-18. The EQs for this exposure pathway are less than one for all potential surface water contaminants, suggesting that there is low potential for adverse effects to the great blue heron due to site-related chemicals in fish caught near the site.

##### **Aquatic Receptors**

Surface Water Organisms--A comparison of modeled surface water concentrations to Federal and State ambient water quality criteria is presented in Table 6-19. Acute surface water concentrations (i.e., groundwater concentrations assumed to be present at the groundwater-surface water interface) exceed Federal AWQCs and/or State of Virginia WQs for arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. Diluted surface water concentrations are less than the chronic Federal AWQCs and Virginia WQs for all chemicals evaluated. As groundwater chemical concentrations will be quickly diluted upon confluence with the Elizabeth River, acute impacts to surface water organisms in the river are not anticipated.

**Benthic Organisms**--A comparison of modeled sediment concentrations to NOAA sediment values is presented in Table 6-20. Sediment IOC concentrations (i.e., concentrations modeled from site groundwater and present at the groundwater-sediment interface) exceed NOAA sediment benchmark values for antimony, arsenic, chromium, lead, and silver. Due to the industrialized nature of the site vicinity and the size of the Elizabeth River, the presence of significant benthic organisms and exposure of sediment organisms to significant amounts of site groundwater chemicals is not expected.

### **6.3.5.3 Uncertainties Associated with the ERA**

The risk measurements used in Superfund RAs are not full probability estimates of risk but are conditional estimates given a set of assumptions about exposure and toxicity. Therefore, it is important to fully specify the assumptions and uncertainties inherent in the ERA to place the risk estimates in proper perspective (EPA, 1988b). Uncertainty analysis is also essential in the FS.

A qualitative uncertainty analysis of each ERA component is sufficient for most sites (EPA, 1988b). Table 6-21 presents the potential uncertainties inherent in the ERA process. A site-specific discussion of these individual components is summarized in the following sections.

#### **Uncertainties Associated with the COPC Selection Process**

**Uncertainties Associated with Data Evaluation**--Uncertainties associated with data evaluation are discussed in the HRA (see Section 6.2.2).

**Uncertainties Associated with the COPC Selection Process**--Since all detected chemicals, with the exception of the essential nutrients calcium, magnesium, potassium, and sodium, are included as COPCs in the ERA, the COPC selection process contains little inherent uncertainty.

#### **Uncertainties Associated with the Exposure Assessment**

Because the actual exposure for ecological receptors is unknown, scenarios are developed to estimate exposure doses that can then be compared with ecotoxicity benchmark concentrations or doses. Ecotoxicity benchmark concentrations are literature-derived values for the lowest concentration or dose of a chemical causing an ecologically interpretable negative response to a test organism. Ecologically interpretable negative responses may be either acute or chronic. These responses include lowered reproductive rates, lowered survival rates, etc.

For surface water, the assumptions are that the organism is exposed to the surface water exposure concentration for a length of time corresponding to the benchmark test conditions. Exposure is unlikely to be continuous for all organisms for several reasons, including:

1. Many aquatic organisms can swim into and out of contaminated zones,
2. Exposure concentrations will fluctuate with changing water levels and other factors, and

3. Many aquatic organisms spend only the larval stage of their life cycles in an aquatic habitat.

Assuming continuous exposure may overestimate the potential for adverse effects. In addition, this scenario estimates the potential uptake from sediments, pore water, and prey items. Because several of the site COPCs may bioaccumulate; uptake from ingestion of prey items by the great blue heron was included as a primary exposure pathway.

#### **Uncertainty Associated with the Toxicity Assessment**

The derivation of an ecological TRV for different chemicals and different indicator species was done using laboratory toxicity data that were available in the literature. To address the considerable amount of uncertainty associated with inter- and intraspecies extrapolation, several uncertainty factors have been applied. This approach may overestimate risks; however, the approach allows for the quantification of ecological risks for many species which do not have published TRVs. These uncertainty factors are a quantitative estimation of uncertainty associated with the value that was selected for use. The preferred value that was sought for use as an ecological TRV was a chronic NOAEL dose. When no chronic NOAEL was available for a chemical in the literature, other values such as LOAELs or LD<sub>50</sub>s were used to derive a "safe dose".

#### **Uncertainty Associated with the Risk Characterization**

The uncertainties of the risk characterization include the uncertainties associated with the previous three steps of the ERA process. In most cases, the uncertainties are more than compensated for by inclusion of upperbound exposure concentrations, upperbound exposure factors, uncertainty factors and modifying factors in developing TRVs, and incorporating conservative assumptions in estimated future risks by assuming that contaminant degradation does not occur. Incorporation of the factors and variables to account for uncertainty in each step of the ERA process presents a reasonable upperbound estimate of the risks and impacts scenario on which to calculate risks. This procedure ensures the protection of health of ecological receptors, because if EQs are less than 1, there is a high level of confidence that an adverse impact will not occur.

#### **6.3.6 Development of RGOs for Ecological Exposure Scenarios**

As exposure of terrestrial receptors to site soils does not provide for any completed exposure pathways, ecological exposure to site soils is not of concern and no RGOs based on exposure of ecological receptors are developed.

Acute surface water concentrations (assumed to be equivalent to groundwater concentrations at the groundwater-surface water confluence; see Table 6-19) exceed Federal AWQC and State WQS for several inorganic chemicals. However, groundwater entering the Elizabeth river would be rapidly diluted. In addition, aquatic receptors are mobile and will not remain in the same exact location for long periods of time. Therefore, due to 1) the large size of the Elizabeth River, 2) the mobility of aquatic receptors, and 3) the lack of potential chronic



effects (Table 6-19), no impacts to aquatic receptors due to site contamination is anticipated and no RGOs based on exposure of ecological receptors are developed.

#### **6.4 Summary and Conclusions**

A summary of HRA and ERA conclusions are presented in the following sections. While the HRA and ERA contain the same risk assessment components, the accepted procedures for conducting the HRA and ERA are sufficiently distinct, however, that the HRA and ERA are discussed separately for each component.

##### **6.4.1 Objectives of the HRA and ERA**

The purpose of the HRA and ERA is to determine the human and ecological health risks associated with the no-action alternative at QADSY and determine which areas, media, and contaminants require further evaluation in the FS. Specific objectives of the process were to:

- Provide an analysis of baseline risks to assist in determining the need for action at these areas,
- Provide a basis for recommendations of RGOs, and
- Provide a consistent method for evaluating and documenting human and ecological health risk at the site.

##### **6.4.2 Summary of the HRA and ERA**

Both the HRA and ERA were conducted based on guidelines developed by EPA. The HRA was based on the Risk Assessment Guidance for Superfund (RAGS), Human Health Evaluation Manual, Parts A and B (EPA, 1989b, 1991b), the Dermal Exposure Assessment document (EPA, 1992), the Exposure Factors Handbook (EPA, 1989a), and EPA Region III Guidance (EPA, 1993a, 1995b). The ERA was based on risk assessment guidance for ecological exposures and assessments (EPA, 1986c, 1988b, 1989c, 1993b) and ECO Updates (issued intermittently by EPA to supplement RAGS). Both the HRA and ERA were divided into 6 primary components as follows:

- Selection of Chemicals of Potential Concern (COPCs)
- Environmental Fate and Transport
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Remedial Goal Objectives (RGOs)

Identification of COPCs involves evaluating the data collected at the site by focusing on potential human and ecological health risks of the chemical(s) under consideration (Section 6.2.1--Human, Section 6.3.1--Ecological). This step requires development of a data set to be carried through the quantitative risk evaluation. The environmental fate and transport analysis is used for evaluating exposure in the exposure assessment, as this is where a variety of phenomena describing the rate at which chemicals move in different media under various environmental conditions, and how those chemicals will migrate to a particular exposure area

or exposure point are determined (Section 6.2.2). The exposure assessment is conducted to estimate the magnitude, frequency, and the pathways of actual and/or potential exposure to human and ecological receptor populations (Section 6.2.3--Human, Section 6.3.3--Ecological). The toxicity assessment (Section 6.2.4--Human, Section 6.3.4--Ecological) summarizes the available human and ecological impacts data as described in published literature, and identifies the dose-response information to be used to calculate health risks. The next to last step in the HRA and ERA, risk characterization (Section 6.2.5--Human, Section 6.3.5--Ecological), integrates the information obtained in the exposure and toxicity assessment sections to determine the health risks associated with potential exposure to site-related contaminants. In addition, a summary of the uncertainties associated with each component of the HRA and ERA is presented in this section. At the completion of risk characterization, the chemicals and media that pose unacceptable risks are identified, and health-based remediation goals, RGOs, are developed (Section 6.2.6--Human, Section 6.3.6--Ecological). The purpose of RGOs is to provide the FS with preliminary goals to be met by the recommended remedial alternative.

#### 6.4.2.1 Identification of COPCs

**Human--**Based on EPA region-wide and Region III RAGS, the COPCs selected for evaluation in the HRA included a subset of IOC, VOCs, and SVOCs (including PAHs, pesticides, and nitroaromatic compounds). The COPCs for the site were identified based on the results of the chemical selection and screening activities and included the following:

##### IOCs

Arsenic

Thallium

##### SVOCs

###### PAHS

Benz(a)anthracene

Benzo(a)pyrene

Benzo(b)fluoranthene

Benzo(k)fluoranthene

Chrysene

Indeno(1,2,3-cd)pyrene

###### Pesticides

Aldrin

BHC, gamma- (Lindane)

Chlordane, alpha-

Chlordane, gamma-

###### Munitions and Nitroaromatics

Dinitrotoluene, 2,4-

Nitrosodi-n-propylamine, N-

##### VOCs

Acetone

Bromodichloromethane

Carbon tetrachloride

Chloroform

DCA, 1,1-

DCE, 1,1-

DCE, 1,2-

Methylene chloride

PCE

TCA, 1,1,1-

TCE

Vinyl chloride

**Ecological**--Based on EPA region-wide and Region III RAGS, the COPCs selected for evaluation in the ERA included a subset of IOC's, VOCs, and SVOCs (including pesticides, PAHs, and nitroaromatic compounds). Due to the number of different species and populations that must be evaluated in an ERA, the guidance on selection of COPCs is not as comprehensive and specific as for selecting COPCs for the HRA, where only one species, humans, is evaluated. Thus, more chemicals were included as COPCs for the ERA to ensure the protection of the different terrestrial and aquatic species at the site. The COPCs for the ERA included the following:

**IOCs**

Antimony  
Arsenic  
Barium  
Beryllium  
Cadmium  
Chromium  
Copper  
Iron  
Lead

Manganese  
Mercury  
Nickel  
Selenium  
Silver  
Thallium  
Vanadium  
Zinc

**SVOCs****Munitions and Nitroaromatics**

Dinitrotoluene, 2,4-

Nitrosodi-n-propylamine, N-

**PAHS**

Acenaphthene  
Benz(a)anthracene  
Benzo(a)pyrene  
Benzo(b)fluoranthene  
Benzo(ghi)perylene  
Benzo(k)fluoranthene

Fluoranthene  
Chrysene  
Indeno(1,2,3-cd)pyrene  
Phenanthrene  
Pyrene

**Pesticides**

Aldrin  
BHC, beta-  
BHC, delta-  
BHC, gamma- (Lindane)  
Chlordane, alpha-

Chlordane, gamma-  
DDD, p,p'-  
DDE, p,p'-  
DDT, p,p'-  
Endosulfan sulfate

**Miscellaneous**

Bis(2-ethylhexyl) phthalate  
Butylbenzyl phthalate  
Di-n-butyl phthalate  
Dichlorobenzene, 1,4-

Dimethylphenol, 2,4-  
Phenol  
Trichlorobenzene, 1,2,4-

**VOCs**

Acetone	Methylene chloride
Benzene	PCE
Bromodichloromethane	Toluene
Carbon tetrachloride	TCA, 1,1,1-
Chloroform	TCE
DCA, 1,1-	Vinyl chloride
DCE, 1,1-	Xylenes
DCE, 1,2-	

**6.4.2.3 Environmental Fate and Transport**

The fate and transport analysis indicates that the VOCs and IOCs present in the soils at QADSY have the potential to migrate to other environmental media and eventually to move toward downgradient locations. The five possible migration pathways identified were:

(1) soil-to-groundwater, (2) soil-to-surface water, (3) soil-to-air, (4) surface water-to-air, (5) groundwater-to-air. These migration pathways were considered when identifying potential exposure pathways in the exposure assessment.

**6.4.2.4 Exposure Assessment**

An exposure pathway describes the course a chemical takes from the source to the exposed receptor. An exposure pathway analysis links the sources, locations, and types of releases with population locations and physical activity patterns to determine the significant exposure pathways of exposure.

**Human**--The primary human exposure pathways quantified in the HRA for the site are as follows:

Exposure Pathway	Medium	Exposure route
Future Residential	Groundwater Surface soil	Inhalation of vapors Ingestion and dermal absorption
Current Worker	Groundwater Surface soil	Inhalation of vapors Ingestion and dermal absorption
Future Worker	Groundwater Surface soil	Inhalation of vapors Ingestion and dermal absorption

Although additional human exposure pathways could exist, they were not included for quantification (i.e., trespasser, site visitor). Potential risks due to these receptors is indirectly

evaluated in the future residential or worker scenario where exposure duration is much greater.

**Ecological**--Due to the lack of exposed soil (the site is gravel-covered and scheduled to be paved) and habitat suitable for food and shelter, exposure of terrestrial mammals to soil was not quantified. The primary ecological exposure pathways quantified in the ERA for the site are for ingestion of fish and direct exposure of aquatic organisms as follows:

Exposure Pathway	Medium	Exposure route
Great Blue Heron	Contaminated Food (Fish)	Ingestion
Freshwater Organisms	Surface Water/Sediment	Direct Contact
Marine Organisms	Surface Water/Sediment	Direct contact

#### 6.4.2.4 Toxicity Assessment

The toxicity assessment summarizes and weighs the available evidence for the potential of a COPC to cause adverse effects in exposed individuals and provides, where possible, an estimate of the relationship between the extent of exposure to a chemical and the increased likelihood and/or severity of adverse effects. The toxicity assessment involves developing profiles for each COPC, summarizing the available toxicological information to include human and ecological health effects, and summarizing criteria and standards. The human health and ecological risks from potential exposure to site contaminants is assessed based on the available toxicity information.

#### 6.4.2.5 Risk Characterization

The risk characterization process defines the nature and degree of adverse human and ecological health effects that may occur from exposure to site-related contaminants under the conditions described in the exposure assessment. In addition, the risk characterization attempts to identify the contaminant source areas associated with the most significant risk so that remedial actions can be targeted in the most cost-effective manner to reduce health risks to acceptable levels. Health risks are determined by integrating the information developed in the three previous steps.

**Human**--For potential human exposures, the potential for noncarcinogenic hazards and carcinogenic risks are calculated separately for each exposure route (i.e., ingestion, dermal absorption) and are reported either as a ratio noncarcinogenic HI or as a probability (cancer risks). The site-specific carcinogenic risk estimates are determined using the RME concentrations and the exposure factors presented in the exposure assessment. The potential risks resulting from exposure to the site contaminants are compared with the EPA target cumulative risk levels. Acceptable exposure levels are the contaminant concentration levels

that present an excess cancer risk of  $10^{-6}$  (1 in 1,000,000) to  $10^{-4}$  (1 in 10,000) to the exposed population, based on the dose-response information for each carcinogenic COPC, (NCP 40 CFR 300, 430:62). When a cumulative carcinogenic risk within a medium (i.e., groundwater) exceeds  $10^{-4}$  (1 in 10,000 excess cancer risk), CERCLA generally requires remedial action at the site (EPA, 1991a). If the cumulative risk is less than  $10^{-4}$ , action generally is not required but may be warranted if a chemical-specific standard that is risk-based (e.g., MCL) is violated. A risk-based remedial decision could be superseded by the presence of noncarcinogenic impact or environmental impact requiring action at the site. Therefore, based on the latest EPA Superfund guidance (1991a), the cumulative risks are compared to  $10^{-4}$ , while the cumulative noncarcinogenic HI are compared to the target HI of 1.

To calculate the total risk to a receptor, risks were added across the pathways if the same individual was assumed to be exposed via multiple pathways (e.g., a person working onsite could be exposed via oral and dermal exposure to soils and inhalation of vapors). The results of the HRA indicate that the scenarios in the following exceed either a cumulative risk of  $10^{-4}$  or an HI of 1:

<u>Exposure Scenario</u>	<u>Risk &gt; Medium</u>	<u>HI &gt; 1</u>			<u>COC Class</u>
		<u>1E-04</u>	<u>Adult</u>	<u>Child</u>	
Future Worker	Air	X	X	NA	VOCs
Future Residential Soil	Air	X	X	X	VOCs
			X	IOC (thallium)	

In addition, the unfiltered concentrations of several IOCs (antimony, arsenic, beryllium, cadmium, chromium, lead, selenium, and thallium), bis(2-ethylhexyl) phthalate, and numerous VOCs (all except chloroform) detected in site groundwater exceed drinking water criteria. However, groundwater beneath the site is not potable, and MCLs and other drinking water criteria are not considered appropriate for evaluating groundwater chemical concentrations at this site.

**Ecological**--The evaluation of potential health risks posed to wildlife is handled in a similar fashion as the evaluation of health risks to humans. The main difference between evaluating ecological versus human health risks is that intra-species differences may significantly affect the amount that an animal ingests per body weight or the sensitivity of a species to adverse health effects. To evaluate potential risks to ecological receptors, the chemical intakes for a particular indicator species are compared to chemical-specific TRVs derived for that species. The ratios of chemical intakes to TRVs are calculated as EQs. EQs less than 1 suggest that the benchmark effect is unlikely to occur in the individual; EQs greater than or equal to 1 require further evaluation. Although these EQs may indicate some potential for adverse effects to individuals, at this point, the potential for adverse effects to populations or ecosystems is

qualified. Although the EQ method does not provide an estimate of uncertainty and is not an estimation of risk, it is commonly used for screening the potential for ecological effects from exposure to hazardous chemicals (EPA, 1988b).

For terrestrial receptors exposed to contaminated food sources (i.e., Great Blue Heron), diluted surface water concentrations were used to estimate the concentration of contaminants in fish. Health risks to a great blue heron ingesting fish from the river are estimated by comparing estimated chemical intakes (from fish ingestion) to TRVs to produce an EQ.

For aquatic receptors, groundwater contaminants are assumed to be discharging to surface water adjacent to the site, resulting in potential bioaccumulation of certain contaminants in fish tissue and potential exposure to aquatic organisms. Exposure of potential surface water receptors to site contaminants was evaluated using two methods. First, onsite groundwater concentrations were compared to acute AWQCs and State of Virginia WQs to evaluate a worst-case scenario of toxicological effects at the groundwater-surface water interface assuming that no physical processes such as dilution, attenuation, or volatilization take place. The level of contamination at the point of discharge is assumed to be equivalent to the level of contamination found in onsite groundwater. A ratio greater than one indicates that the potential may exist for adverse effects to occur in an organism exposed to chemical concentrations at the groundwater-surface water interface.

Second, surface water contaminant concentrations that may be found in the open river were modeled from onsite groundwater concentrations using a dilution factor. These modeled concentrations were compared to chronic Federal AWQCs and Virginia WQs to evaluate the potential exposure of aquatic organisms in the area. A ratio greater than one indicates that the potential may exist for adverse effects to occur in an organism exposed to diluted chemical concentrations in the river.

Potential impacts to organisms inhabiting river sediments near the site are evaluated using the NOAA (1990) sediment benchmarks for LOAELs in aquatic organisms. Sediment concentrations modelled from the groundwater concentrations at the groundwater-surface water interface were compared to the NOAA values. A ratio greater than one indicates that the potential may exist for adverse effects in organisms exposed to sediments with the modelled chemical concentration.

The risks results for evaluating ecological exposures are as follows:

<u>Exposure Scenario</u> <u>Class</u>	<u>Medium</u>	<u>EQ &gt; 1</u>	<u>COC</u>
Aquatic Organisms	Surface Water	X	IOCs
Benthic Organisms	Sediment	X	IOCs

#### 6.4.2.6 RGOs

SARA requires that remedial actions attain a degree of contaminant cleanup that ensures the protection of public health and the environment. Thus, the risk characterization results are used to identify whether site COPCs need to be reduced to acceptable health-based levels. The acceptable health-based levels are referred to as RGOs, which are chemical-specific concentration goals for individual chemicals for specific medium and reasonable land use combinations.

Based on the results of the HRA and ERA risk characterization, excess risk, HIs, and EQs were determined based on the current and future land use scenarios. In summary, RGOs were developed for several VOCs in groundwater. These RGOs are developed as a result of excess human risk ( $> 1 \times 10^{-4}$ ) due to inhalation of vapors from groundwater. Thus, all chemicals contributing an individual risk of  $1 \times 10^{-6}$  or greater were included for RGO development for groundwater to provide risk managers with the maximum risk-related media level options on which to develop remediation aspects of the FS. A summary of the COCs included for RGO development based on the HRA and ERA include:

<u>COC for RGO</u>	<u>Development</u>	<u>Scenario</u>
<u>Medium</u>		
Groundwater	Carbon tetrachloride	Future Worker and
Residential		
Chloroform	Future Worker and Residential	
DCA, 1,1-	Future Residential	
DCE, 1,1-	Future Worker and Residential	
PCE	Future Worker and Residential	
TCA, 1,1,1-	Future Residential	
TCE	Future Worker and Residential	
Vinyl chloride	Future Worker and Residential	

#### 6.4.3 Conclusions

##### 6.4.3.1 Groundwater Contamination

Current exposure scenarios applicable to the QADSY are not expected to result in unacceptable impacts to the health of human or ecological receptors based on the exposure conditions evaluated. However, based on theoretical future exposure of workers or residents (a highly unlikely future scenario), remediation of site groundwater to reduce the risk associated with inhalation of contaminant vapors in indoor air may be warranted.

##### 6.4.3.2 Soil Contamination

As the site is covered with six to eight inches of gravel and scheduled to be paved and the site vicinity is paved, no exposure to site soils is anticipated according to current and future use plans. Should the site use change in the future (i.e., construction of homes, businesses, etc.) such that site soil becomes exposed, exposure to site soils should be re-evaluated.



Table 6-1. Comparison of Maximum Detected Chemical Concentrations in Soil to RBCs (Page 1 of 2)

Analyte	Maximum Detected Soil Concentration (mg/kg)	Oral RfD	Oral CSF	RBC for Residential Soil Ingestion *		Does Detected Concentration Exceed RBC?
				Concentration (mg/kg)	Basis	
Acenaphthene	2.00E+00	6.0E-02	NC	4.7E+03	N	No
Acetone	6.50E-01	1.0E-01	NC	7.8E+03	N	No
Aldrin	1.40E-03	3.0E-05	1.7E+01	3.8E-02	C	No
Aluminum	5.55E+03	1.0E+00	NC	7.8E+04	N	No
Antimony	3.20E+00	4.0E-04	NC	3.1E+01	N	No
Arsenic	3.20E+01	3.0E-04	1.5E+00	4.3E-01	C	Yes
Barium	5.66E+01	7.0E-02	NC	5.5E+03	N	No
Benz(a)anthracene	2.60E-01	3.0E-02 a	7.3E-01	8.7E-01	C	No
Benzene	2.00E-03	3.0E-04	2.9E-02	2.2E+01	C	No
Benzo(a)pyrene	8.50E-02	3.0E-02 a	7.3E+00	8.7E-02	C	No
Benzo(b)fluoranthene	1.30E-01	3.0E-02 a	7.3E-01	8.7E-01	C	No
Benzo(ghi)perylene	7.80E-02	3.0E-02 a	NC	2.3E+03	N	No
Benzo(k)fluoranthene	6.10E-02	3.0E-02 a	7.3E-02	8.7E+00	C	No
BHC, beta-	4.00E-03	3.0E-04 b	1.8E+00	3.5E-01	C	No
BHC, delta-	1.10E-03	3.0E-04 b	NC	2.3E+01	N	No
BHC, gamma- (Lindane)	1.10E-03	3.0E-04	1.3E+00	4.9E-01	C	No
Bis(2-ethylhexyl) phthalate	1.00E-01	2.0E-02	1.4E-02	4.6E+01	C	No
Butylbenzyl phthalate	5.30E-01	2.0E-01	NC	1.6E+04	N	No
Cadmium (solid matrix)	2.00E+00	1.0E-03	NC	7.8E+01	N	No
Calcium	1.36E+05	nd	NC	-	-	-
Chlordane, alpha-	1.20E-02	6.0E-05 c	1.3E+00 c	4.9E-01	C	No
Chlordane, gamma-	1.40E-02	6.0E-05 c	1.3E+00 c	4.9E-01	C	No
Chromium, total	2.00E+01	5.0E-03 d	NC	3.9E+02	N	No
Chrysene	2.60E-01	3.0E-02 a	7.3E-03	8.7E+01	C	No
Copper	2.43E+01	3.7E-02	NC	2.9E+03	N	No
DDD, p,p'-	1.60E-01	5.0E-04 e	2.4E-01	2.7E+00	C	No
DDE, p,p'-	5.70E-03	5.0E-04 e	3.4E-01	1.9E+00	C	No
DDT, p,p'-	2.10E-03	5.0E-04	3.4E-01	1.9E+00	C	No
Di-n-butyl phthalate	2.00E+00	1.0E-01	NC	7.8E+03	N	No
Dichlorobenzene, 1,4-	2.00E+00	2.1E-03	2.4E-02	2.7E+01	C	No
Dichloroethene, 1,1-	5.00E-03	9.0E-03	6.0E-01	1.1E+00	C	No
Dichloroethenes, 1,2-, total	1.50E+00	9.0E-03	NC	7.0E+02	N	No
Dimethylphenol, 2,4-	4.80E+00	2.0E-02	NC	1.6E+03	N	No
Dinitrotoluene, 2,4-	1.80E+00	2.0E-03	6.8E-01	9.4E-01	C	Yes
Endosulfan sulfate	2.10E-02	6.0E-03 f	NC	4.7E+02	N	No
Fluoranthene	7.00E-01	4.0E-02	NC	3.1E+03	N	No
Indeno(1,2,3-cd)pyrene	8.30E-02	3.0E-02 a	7.3E-01	8.7E-01	C	No
Iron	1.74E+04	3.0E-01	NC	2.3E+04	N	No
Lead	1.05E+02	nd g	nd g	4.0E+02 h	N	No
Magnesium	5.50E+03	nd	NC	-	-	-
Manganese	3.62E+02	4.7E-02	NC	3.7E+03	N	No
Mercury	2.40E-01	3.0E-04	NC	2.3E+01	N	No
Methylene chloride	3.90E-02	6.0E-02	7.5E-03	8.5E+01	C	No
Nickel	2.20E+01	2.0E-02	NC	1.6E+03	N	No

Table 6-1. Comparison of Maximum Detected Chemical Concentrations in Soil to RBCs (Page 2 of 2)

Analyte	Maximum Detected Soil Concentration (mg/kg)	Oral RfD	Oral CSF	RBC for Residential Soil Ingestion *		Does Detected Concentration Exceed RBC?
				Concentration (mg/kg)	Basis	
Nitrosodi-N-propylamine, N-	1.00E+01	9.5E-03	7.0E+00	9.1E-02	C	Yes
Phenanthrene	6.00E-01	3.0E-02 a	NC	2.3E+03	N	No
Phenol	3.40E+00	6.0E-01	NC	4.7E+04	N	No
Potassium	2.80E+03	nd	NC	-	-	-
Pyrene	1.80E+00	3.0E-02	NC	2.3E+03	N	No
Silver	1.00E+00	5.0E-03	NC	3.9E+02	N	No
Sodium	1.14E+03	nd	NC	-	-	-
Tetrachloroethene	1.50E-01	1.0E-02	5.2E-02	1.2E+01	C	No
Thallium	2.20E+01	8.0E-05 i	NC	6.3E+00	N	Yes
Toluene	1.40E-01	2.0E-01	NC	1.6E+04	N	No
Trichlorobenzene, 1,2,4-	2.00E+00	1.0E-02	NC	7.8E+02	N	No
Trichloroethane, 1,1,1-	1.00E-03	9.0E-02	NC	7.0E+03	N	No
Vanadium	5.32E+01	7.0E-03	NC	5.5E+02	N	No
Xylenes	2.00E-03	2.0E+00	NC	1.6E+05	N	No
Zinc	1.00E+02	3.0E-01	NC	2.3E+04	N	No

Note: nd = not determined.  
NC = not classified as a carcinogen.  
- = not evaluated due to lack of a RfD.

Basis: C = carcinogenic effects.  
N = noncarcinogenic effects.

- (a) No RfD is available for this PAH; the lowest RfD for a non-naphthalene PAH (pyrene) is used.
- (b) No RfD is available for this BHC isomer; the RfD for gamma-BHC (lindane) is used.
- (c) No RfD or CSF is available for individual chlordane isomers; the RfD and CSF for total chlordane is used.
- (d) The more conservative RfD for hexavalent chromium is used.
- (e) No RfD is available for p,p'-DDD or p,p'-DDE; the RfD for the parent compound, p,p'-DDT, is used.
- (f) No RfD is available for endosulfan sulfate; the RfD for the parent compound, endosulfan, is used.
- (g) No RfD or CSF has been developed for lead; EPA (Agency-wide and Region III) prefers to use the Integrated Exposure Uptake Biokinetic (IEUBK) Model to predict blood-lead levels (EPA, 1994a).
- (h) Indicated value is the recommended default screening value for lead in soils based on residential child exposure (EPA, 1994a).
- (i) No RfD is available for thallium metal; the lowest RfD for a thallium salt, thallium oxide, is used.

\* RBCs calculated using formulas provided by EPA (1995b) and the most recent RfDs and CSFs from EPA sources (IRIS, 1996; EPA, 1995a, 1995b).

Source: ESE.

{QDRUM-RA3V-RBCSO.WQ1/dbc/06May96}

Table 6-2. Comparison of Metals Concentrations (mg/kg) in Site-Specific and Background Soils \*

IOC	Background *		QADSY		
	Mean Soil Concentration (mg/kg)	Frequency of Detection	Maximum Soil Concentration (mg/kg)	Frequency of Detection	Is Site Soil Concentration > 2X Background Concentration?
Aluminum	6.28E+03	7 / 7	5.55E+03	5 / 5	No
Antimony	3.34E+01	1 / 7	3.20E+00	1 / 5	No
Arsenic	5.13E+00	6 / 7	3.20E+01	16 / 17	Yes
Barium	2.48E+01	7 / 7	5.66E+01	5 / 5	Yes
Cadmium	1.38E+00	2 / 7	2.00E+00	12 / 12	No
Calcium	3.08E+04	7 / 7	1.36E+05	5 / 5	Yes
Chromium	1.09E+01	7 / 7	2.00E+01	17 / 17	No
Copper	3.58E+00	6 / 7	2.43E+01	17 / 17	Yes
Iron	7.34E+03	7 / 7	1.74E+04	5 / 5	Yes
Lead	1.25E+01	7 / 7	1.05E+02	17 / 17	Yes
Magnesium	6.68E+02	7 / 7	5.50E+03	5 / 5	Yes
Manganese	7.54E+01	7 / 7	3.62E+02	5 / 5	Yes
Mercury	4.55E-01	1 / 7	2.40E-01	12 / 12	No
Nickel	2.53E+01	1 / 7	2.20E+01	17 / 17	No
Potassium	4.41E+02	7 / 7	2.80E+03	5 / 5	Yes
Silver	5.95E+00	1 / 7	1.00E+00	2 / 12	No
Sodium	4.08E+02	6 / 7	1.14E+03	1 / 1	Yes
Thallium	NA	--	2.20E+01	12 / 12	NC **
Vanadium	2.07E+01	6 / 7	5.32E+01	5 / 5	Yes
Zinc	2.31E+01	7 / 7	1.00E+02	17 / 17	Yes

Note: NA = not analyzed.  
NC = not calculated.

\* Based on data for background well borings (all depths) from the Building LP-20 site on Norfolk Naval Base. This data was provided by Baker Environmental.

\*\* Since background samples were not analyzed for this constituent, this IOC is included for further evaluation.

Source: ESE.

{QDRUM-PA3V-BKDSO.WQ1/dbc/08May96}

Table 6-3. Inorganic Essential Nutrients: Comparison of Maximum Daily Intakes from Soil to RDAs

Inorganic Nutrient	Minimum RDA (mg/day) *		Maximum Concentration (mg/kg)	Adult		Child	
	Adult	Child		Daily Intake ** (mg/day)	Does Intake Exceed RDA?	Daily Intake ** (mg/day)	Does Intake Exceed RDA?
Calcium	800	400	1.36E+05	1.30E+01	No	2.61E+01	No
Magnesium	200	40	5.50E+03	5.27E-01	No	1.05E+00	No
Potassium	2000	500	2.80E+03	2.68E-01	No	5.37E-01	No
Sodium	500	120	1.14E+03	1.09E-01	No	2.19E-01	No

\* Sodium value is an estimated minimum requirement for a healthy person. No allowance has been made for large, prolonged losses of this electrolyte through perspiration.

\*\* Daily intake was calculated using Chemical Intake Equations from EPA Superfund Risk Assessment Guidance (EPA, 1989a, 1991) as follows. Exposure factors are default values from these documents intended for screening level analysis and may not represent site-specific conditions.

$$\text{Soil Daily Intake (mg/day)} = \frac{\text{Soil Conc (mg/kg)} * \text{Ingestion Rate} * \text{Conversion Factor} * \text{Exposure Frequency} * \text{Exposure Duration}}{\text{Averaging Time}}$$

$$\text{Adult Resident} = \frac{\text{Soil Conc. (mg/kg)} * 100 \text{ mg/day} * 1\text{E-}06 \text{ kg/gm} * 350 \text{ days/yr} * 30 \text{ yr}}{365 \text{ days/yr} * 30 \text{ yrs}}$$

$$\text{Child Resident} = \frac{\text{Soil Conc. (mg/kg)} * 200 \text{ mg/day} * 1\text{E-}06 \text{ kg/gm} * 350 \text{ days/yr} * 6 \text{ yr}}{365 \text{ days/yr} * 6 \text{ yrs}}$$

Source: ESE.

Table 6-4. Comparison of Maximum Detected Chemical Concentrations in Groundwater to RBCs and MCLs

Analyte	Maximum Detected Groundwater Concentration (mg/L)	Inhalation RfD	Inhalation CSF	RBC Based On Residential Inhalation of VOCs in Groundwater *		MCL (mg/L)	Does Maximum Detected Concentration Exceed Indicated Criterion?	
				Concentration (mg/L)	Basis		RBC	MCL
IOCs								
Antimony	5.20E-02	nd	nc	nv	N N	6.00E-03	--	Yes
Arsenic	1.20E-01	nd	1.5E+01	nv	C N	5.00E-02	--	Yes
Barium	1.73E-01	1.4E-04	nc	nv	N N	2.00E+00	--	No
Beryllium	5.00E-03	nd	8.4E+00	nv	N N	4.00E-03	--	Yes
Cadmium	1.50E-02	nd	6.3E+00	nv	N N	5.00E-03	--	Yes
Calcium	5.05E+02	nd	nc	nv	N N	ND	--	ND
Chromium, total	2.06E-01	nd	4.2E+01	nv	N N	1.00E-01	--	Yes
Copper	5.50E-02	nd	nc	nv	N N	1.30E+00 (a)	--	No
Iron	7.79E+00	nd	nc	nv	N N	ND	--	ND
Lead	1.02E-01	nd	nc	nv	N N	1.50E-02 (b)	--	Yes
Magnesium	7.96E+02	nd	nc	nv	N N	ND	--	ND
Manganese	2.73E+00	1.4E-05	nc	nv	N N	ND	--	ND
Mercury	3.00E-04	8.6E-05	nc	nv	N N	2.00E-03	--	No
Nickel	8.70E-02	nd	8.4E-01	nv	N N	1.00E-01	--	No
Potassium	2.37E+02	nd	nc	nv	N N	ND	--	ND
Selenium	9.00E-02	5.0E-03	nc	nv	N N	5.00E-02	--	Yes
Silver	1.20E-02	nd	nc	nv	N N	ND	--	ND
Sodium	6.66E+03	nd	nc	nv	N N	ND	--	ND
Thallium	5.50E-03	nd	nc	nv	N N	5.00E-04	--	Yes
Zinc	4.16E-01	nd	nc	nv	N N	ND	--	ND
SVOCs								
Bis(2-ethylhexyl) phthalate	5.40E-02	nd	nd	nv	C N	6.00E-03	--	Yes
VOCs								
Acetone	1.30E+00	1.0E-01	nc	2.6E-01	N V	ND	Yes	ND
Bromodichloromethane	1.20E-01	2.0E-02	6.2E-02	2.0E-04	C V	1.00E-01 (c)	Yes	Yes
Carbon tetrachloride	1.20E-01	5.7E-04	5.3E-02	2.4E-04	C V	5.00E-03	Yes	Yes
Chloroform	6.00E-02	1.0E-02	8.1E-02	1.5E-04	C V	1.00E-01 (c)	Yes	No
Dichloroethane, 1,1-	5.40E-01	1.4E-01	nc	3.7E-01	N V	ND	Yes	ND
Dichloroethene, 1,1-	1.40E-01	9.0E-03	1.8E-01	7.0E-05	C V	7.00E-03	Yes	Yes
Dichloroethenes, 1,2-, total	5.00E-01	9.0E-03	nc	2.3E-02	N V	7.00E-02 (d)	Yes	Yes
Methylene chloride	9.00E-03	8.6E-01	1.6E-03	7.8E-03	C V	5.00E-03	Yes	Yes
Tetrachloroethene	1.55E-01	1.0E-02	2.0E-03	6.3E-03	C V	5.00E-03	Yes	Yes
Trichloroethane, 1,1,1-	1.10E+00	2.9E-01	nc	7.6E-01	N V	2.00E-01	Yes	Yes
Trichloroethene	1.37E+00	6.0E-03	6.0E-03	2.1E-03	C V	5.00E-03	Yes	Yes
Vinyl chloride	3.40E-02	1.3E-03	3.0E-01	4.2E-05	C V	2.00E-03	Yes	Yes

Note: nc = not classified as a carcinogen.  
 nd = not determined.  
 nv = not volatile.  
 -- = since groundwater is not potable, no exposure to this nonvolatile chemical is expected to occur.

Basis: C N = carcinogenic effects; nonvolatile chemical.  
 C V = carcinogenic effects; volatile chemical.  
 N N = noncarcinogenic effects; nonvolatile chemical.  
 N V = noncarcinogenic effects; volatile chemical.

- (a) No MCL has been determined; indicated value is the MCLG.  
 (b) No MCL has been determined; indicated value is the drinking water action level.  
 (c) Value for total trihalomethanes.  
 (d) Value for the more toxic cis- isomer.

\* RBCs based on formulas provided by EPA (1995b) and the most recent RfDs and CSFs from EPA sources (IRIS, 1996; EPA, 1995a, 1995b).

Source: ESE.

Table 6-5. COPCs for the HRA and Media in Which Detected/Modeled

Chemical	Soil	Groundwater	Indoor Air
<b>IOCs</b>			
Arsenic	M,S	-	-
Thallium	M	-	-
<b>Munitions/Nitroaromatic Compounds</b>			
Dinitrotoluene, 2,4-	M	-	-
Nitrosodi-n-propylamine, N-	M	-	-
<b>PAHs</b>			
Benz(a)anthracene	M,S	-	-
Benzo(a)pyrene	S	-	-
Benzo(b)fluoranthene	S	-	-
Benzo(k)fluoranthene	S	-	-
Chrysene	M,S	-	-
Indeno(1,2,3-cd)pyrene	S	-	-
<b>Pesticides</b>			
Aldrin	S	-	-
Chlordane, alpha-	S	-	-
Chlordane, gamma-	S	-	-
Lindane	S	-	-
<b>VOCs, misc.</b>			
Acetone	-	E	G
Bromodichloromethane	-	E	G
Carbon tetrachloride	-	E	G
Chloroform	-	E	G
Dichloroethane, 1,1-	-	E,S	G
Dichloroethene, 1,1-	-	E	G
Dichloroethene, 1,2-	-	E,S	G
Methylene chloride	-	E	G
Tetrachloroethene	-	E,S	G
Trichloroethane, 1,1,1-	-	E	G
Trichloroethene	-	E,S	G
Vinyl chloride	-	E	G

Note: E = COPC detected in previous ESE samples from the designated medium.  
 G = COPC modeled from groundwater into the designated medium by ESE.  
 M = COPC detected in the designated medium by Malcolm Pirnie.  
 S = COPC detected in 1995 ESE samples from the designated medium.  
 - = not applicable for this medium.

Source: ESE.

{QDRUM-RA3/V-COPCH.TBL/dbc/06May96}

Table 6-6. Chemical-Specific Input Parameters for the Groundwater-to-Indoor Air Model

COPC	Da <sup>(a)</sup> (cm <sup>2</sup> /year)	H <sup>(b)</sup>	C <sub>gw</sub> (µg/L)	C <sub>air</sub> (µg/m <sup>3</sup> )	MW <sup>(c)</sup> (g/mole)
Acetone	1.59 x 10 <sup>6</sup>	0.000919	1,300	0.21	58
Bromodichloromethane <sup>(a)</sup>	9.6 x 10 <sup>5</sup>	0.107	102	0.972	164
Carbon tetrachloride	9.9 x 10 <sup>5</sup>	1.07	102	10	154
Chloroform	1.12 x 10 <sup>6</sup>	0.128	60	0.95	119
1,1-Dichloroethane	1.23 x 10 <sup>6</sup>	0.192	540	14.1	99
1,1-Dichloroethene	1.24 x 10 <sup>6</sup>	1.52	140	17.3	97
1,2-Dichloroethene	1.24 x 10 <sup>6</sup>	0.315	500	11.4	97
Methylene chloride	1.32 x 10 <sup>6</sup>	0.091	9	8.4	85
Tetrachloroethene	9.5 x 10 <sup>5</sup>	1.16	155	3.3	166
1,1,1-Trichloroethane	1.06 x 10 <sup>6</sup>	0.642	1,100	82.7	133
Trichloroethene	1.07 x 10 <sup>6</sup>	0.41	1,370	14.5	131
Vinyl Chloride	1.53 x 10 <sup>6</sup>	3.65	34	12.1	63

Note: C<sub>air</sub> = concentration in indoor air.  
C<sub>gw</sub> = concentration in groundwater.  
Da = diffusion coefficient in air.  
H = Henry's Law constant.  
MW = molecular weight.

<sup>(a)</sup> Lyman *et al.*, 1982.

<sup>(b)</sup> EPA, 1986d.

<sup>(c)</sup> ATSDR, 1988a.

\*Based on the following formula:

$$\frac{Da_1}{Da_2} = \sqrt{\frac{MW_2}{MW_1}}$$

Source: ESE.

{QDRUM-RA3/V-AIRFACT.TBL/dbc/06May96}

Table 6-7. Chronic Dose-Response Toxicity Constants for the HRA COPCs (Page 1 of 3)

Chemical	Oral RfD (UF)*	Inhal RfD (UF)**	Oral CSF*	Oral WoE*	Inhal CSF***	Inhal WoE*
<b>Inorganic Chemicals (IOC)</b>						
Arsenic	3.0E-04 (3)	--	1.5E+00	A	1.5E+01 <sup>†</sup>	A
Thallium	8.0E-05 <sup>††</sup> (3,000)	--	--		--	
<b>Nitro Compounds / Explosives</b>						
Dinitrotoluene, 2,4-	2.0E-03 (100)	--	6.8E-01 <sup>N1</sup>	B2	nd <sup>N2,†</sup>	B2
Nitrosodi-N-propylamine, N-	9.5E-03 <sup>N3</sup> (100,000)	--	7.0E+00	B2	nd <sup>N2,†</sup>	B2
<b>Pesticides</b>						
Aldrin	3.0E-05 (1,000)	--	1.7E+01	B2	1.7E+01	B2
BHC, gamma- (Lindane)	3.0E-04 (1,000)	--	1.3E+00 <sup>†</sup>	B2/C	nd <sup>P2</sup>	B2/C
Chlordane, alpha-	6.0E-05 <sup>P1</sup> (1,000)	--	1.3E+00 <sup>P1</sup>	B2	1.3E+00 <sup>P1</sup>	B2
Chlordane, gamma-	6.0E-05 <sup>P1</sup> (1,000)	--	1.3E+00 <sup>P1</sup>	B2	1.3E+00 <sup>P1</sup>	B2
<b>Polycyclic Aromatic Hydrocarbons (PAHs)</b>						
Benz(a)anthracene	3.0E-02 <sup>H1</sup> (3,000)	--	7.3E-01 <sup>H2</sup>	B2	6.1E-01 <sup>H2</sup>	B2
Benzo(b)fluoranthene	3.0E-02 <sup>H1</sup> (3,000)	--	7.3E-01 <sup>H2</sup>	B2	6.1E-01 <sup>H2</sup>	B2
Benzo(k)fluoranthene	3.0E-02 <sup>H1</sup> (3,000)	--	7.3E-02 <sup>H2</sup>	B2	6.1E-02 <sup>H2</sup>	B2
Benzo(a)pyrene	3.0E-02 <sup>H1</sup> (3,000)	--	7.3E+00	B2	6.1E+00	B2
Chrysene	3.0E-02 <sup>H1</sup> (3,000)	--	7.3E-03 <sup>H2</sup>	B2	6.1E-03 <sup>H2</sup>	B2
Indeno(1,2,3-cd)pyrene	3.0E-02 <sup>H1</sup> (3,000)	--	7.3E-01 <sup>H2</sup>	B2	6.1E-01 <sup>H2</sup>	B2
<b>Miscellaneous Volatile Organic Chemicals (VOC)</b>						
Acetone	1.0E-01 (1,000)	--	--		--	
Bromodichloromethane	2.0E-02 (1,000)	--	6.2E-02	B2	nd <sup>V1</sup>	B2
Carbon tetrachloride	7.0E-04 (1,000)	5.7E-04 <sup>##</sup> (na)	1.3E-01	B2	5.3E-02	B2
Chloroform	1.0E-02 (1,000)	--	6.1E-03	B2	8.1E-02 <sup>†</sup>	B2
Dichloroethane, 1,1-	1.0E-01 <sup>†</sup> (1,000)	1.4E-01 <sup>†</sup> (1,000)	nd <sup>V2</sup>	C	nd <sup>V3</sup>	C
Dichloroethene, 1,1-	9.0E-03 (1,000)	--	6.0E-01	C	1.8E-01 <sup>##</sup>	C
Dichloroethenes, 1,2-, total	9.0E-03 <sup>†</sup> (1,000)	--	--		--	



Table 6-7. Chronic Dose-Response Toxicity Constants for the HRA COPCs (Page 2 of 3)

Chemical	Oral RfD (UF)*	Inhal RfD (UF)**	Oral CSF*	Oral WoE*	Inhal CSF***	Inhal WoE*
<b>VOCs, cont.</b>						
Methylene chloride	6.0E-02 (100)	8.6E-01' (100)	7.5E-03	B2	1.6E-03	B2
Tetrachloroethene	1.0E-02 (1,000)	--	5.2E-02 <sup>V4,##</sup>	B2 <sup>V4</sup>	1.8E-03 <sup>V4,##</sup>	B2 <sup>V4</sup>
Trichloroethane, 1,1,1-	9.0E-02' (1,000)	2.9E-01' (1,000)	--		--	
Trichloroethene	6.0E-03 <sup>##</sup> (na)	--	1.1E-02 <sup>V4,##</sup>	B2 <sup>V4</sup>	6.0E-03 <sup>V4,##</sup>	B2 <sup>V4</sup>
Vinyl chloride	1.3E-03 <sup>V5</sup> (100)	--	1.9E+00 <sup>#</sup>	A	3.0E-01'	A

Note:

- RfD = reference dose [mg/kg/day].
- UF = uncertainty factor.
- MF = modifying factor.
- CSF = cancer slope factor [(mg/kg/day)<sup>-1</sup>].
- WoE = weight of evidence for ranking as a human carcinogen (see Table 6-8).
- inhal = inhalation.
- na = not applicable.
- nd = not determined.
- MRL = minimal risk level.
- mg/kg/day = milligrams per kilogram per day.
- mg/L = milligrams per liter.
- µg/L = micrograms per liter.
- L/day = liters per day.

- (H1) No RfD is available for this PAH; the lowest non-naphthalene value (pyrene) is used for comparison, only.
- (H2) CSF for this potentially carcinogenic PAH is an interim value from EPA ECAO and listed in EPA Region III's Risk-Based Concentration Table, July - December 1995 (EPA, 1995b). The value is based on the CSF for benzo(a)pyrene and the following Toxicity Equivalency Factors: benz(a)anthracene, 0.1; benzo(b)fluoranthene, 0.1; benzo(k)fluoranthene, 0.01; chrysene, 0.001; dibenz(ah)anthracene, 1.0; and indeno(1,2,3-cd)pyrene, 0.1.
- (I1) No oral RfD is available for metallic thallium; the listed value for thallium chloride is from HEAST (EPA, 1995a).
- (N1) No oral CSF is available for this nitro compound alone; the listed value is for 2,4-dinitrotoluene/2,6-dinitrotoluene mixture.

Table 6-7. Chronic Dose-Response Toxicity Constants for the HRA COPCs (Page 3 of 3)

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- (N2) Although EPA has classified this chemical as a Group B2 suspect human carcinogen via inhalation, no CSF has been developed for this exposure pathway.
- (N3) Oral RfD for N-nitrosodi-N-propylamine based on an acute oral MRL for rats of 0.095 mg/kg/day (ATSDR, 1988b) and an uncertainty factor of 10 (for acute-to-chronic extrapolation).
- (P1) No RfD or CSF is available for individual chlordane isomers; listed values are for total chlordane.
- (P2) Although EPA has classified this pesticide as a Group B2/C suspect human carcinogen via inhalation, no CSF has been developed for this exposure pathway.
- (V1) Although EPA has classified this chemical as a Group B2 suspect human carcinogen via inhalation, no CSF has been developed for this exposure pathway.
- (V2) Although EPA has classified this chemical as a Group C possible human carcinogen via ingestion, no CSF has been developed for this exposure pathway.
- (V3) Although EPA has classified this chemical as a Group C possible human carcinogen via inhalation, no CSF has been developed for this exposure pathway.
- (V4) CSFs and WoEs for this VOC have been withdrawn from IRIS pending further review.
- (V5) Listed value for vinyl chloride is the chronic oral MRL (ATSDR, 1989b).

\*All oral RfDs, oral CSFs, and WoEs are available in IRIS (1996), unless otherwise noted.

\*\*Inhalation RfDs are based on the inhalation RfC available in IRIS (1996) and assume that a healthy 70-kilogram adult inhales 20 m<sup>3</sup>/day air, unless otherwise noted.

\*\*\*Inhalation CSFs are based on the inhalation UR available in IRIS (1996) and assume that a healthy 70-kilogram adult inhales 20 m<sup>3</sup>/day air, unless otherwise noted.

\*Value available in HEAST, 1995 Annual Update (EPA, 1995a).

\*\*Provisional value available from the EPA-NCEA Superfund Health Risk Technical Support Center and presented in EPA Region III's Risk-Based Concentration Table, July - December 1995 (EPA, 1995b).

Source: ESE.

{QDRUM-RA3/H-BIOPRP.TBL/dbc/07May96}

Table 6-8. Weight-of-Evidence Categories for Potential Carcinogens

EPA Category	Description of Group	Description of Evidence
Group A	Human carcinogen	Sufficient evidence from epidemiologic studies to support a causal association between exposure and cancer
Group B1	Probable human carcinogen	Limited evidence of carcinogenicity in humans from epidemiologic studies
Group B2	Probable human carcinogen	Sufficient evidence of carcinogenicity in animals but inadequate data in humans
Group C	Possible human carcinogen	Limited evidence of carcinogenicity in animals
Group D	Not classified	Inadequate evidence of carcinogenicity in animals
Group E	No evidence of carcinogenicity in humans	No evidence of carcinogenicity in at least two adequate animal tests or in both epidemiologic and animal studies

Source: IRIS, 1996.

{QDRUM-RA3/V-WOE.TBL/dbc/06May96}

Table 6-9. Summary of Human HIs and Risks (Page 1 of 2)

Scenario	Receptor	Exposure Medium	Exposure Pathway	HI	Risk
Current Worker	Adult	Air	Inhalation	2E-01	4E-05
		Soil	Dermal Oral	1E-02 4E-03	4E-06 2E-07
			Subtotal	1E-02	4E-06
		TOTAL		2E-01	4E-05
Future Worker	Adult	Air	Inhalation	4E+00	9E-04
		Soil	Dermal Oral	5E-02 8E-02	2E-05 3E-06
			Subtotal	1E-01	2E-05
		TOTAL		4E+00	9E-04
Future Residential	Adult	Air	Inhalation	4E+00	---
		Soil	Dermal Oral	8E-02 2E-01	--- ---
			Subtotal	3E-01	---
		TOTAL		5E+00	---
	Child	Air	Inhalation	2E+01	---
		Soil	Dermal Oral	2E-01 2E+00	--- ---
			Subtotal	2E+00	---
		TOTAL		2E+01	---

Table 6-9. Summary of Human HIs and Risks (Page 2 of 2)

Scenario	Receptor	Exposure Medium	Exposure Pathway	HI	Risk
Future Residential, cont.	Lifetime	Air	Inhalation	---	1E-03
		Soil	Dermal	---	4E-05
			Oral	---	3E-05
			Subtotal	---	7E-05
		TOTAL			---

Note: --- = not evaluated for this exposure scenario.

Source: ESE.

{QDRUM-PA3/V-RSKSUM.WQ1/dbc/08May96}

Table 6-10. Uncertainties in the HRA Process

HRA Component	Potential for Uncertainty
COPC Selection	<ul style="list-style-type: none"> <li>• Chemical monitoring data collected over time, analyzed by different laboratories, and evaluated using varying quality assurance methodology</li> <li>• Presence of tentatively identified compounds (TICs)</li> <li>• Current and future land uses</li> <li>• Risk-based concentration screening</li> </ul>
Exposure Assessment	<ul style="list-style-type: none"> <li>• Selection of site-specific exposure pathways</li> <li>• Estimation of indoor air exposure concentrations without monitoring data</li> <li>• Estimation of exposure to multiple substances</li> <li>• Estimation of exposure parameters</li> </ul>
Toxicity Assessment	<ul style="list-style-type: none"> <li>• Selection of toxicity values</li> <li>• Factors used in derivation of reference doses (RfDs), including interspecies extrapolation</li> <li>• Weight-of-evidence for human carcinogenicity</li> <li>• Derivation of carcinogenic slope factors (CSFs)</li> <li>• Extrapolation of less-than-lifetime exposure to lifetime cancer risks</li> <li>• Interaction of multiple substances</li> </ul>
Risk Characterization	<ul style="list-style-type: none"> <li>• Addition of risks across multiple exposure pathways</li> <li>• Addition of risks from multiple substances</li> </ul>

Source: ESE.

{QDRUM-RA3/V-UNCRTH.TBL/dbc/06May96}

Table 6-11. Preliminary RGOs Associated with Human Inhalation of Vapors from Groundwater Based on a Cumulative Risk of 1E-4 or HI of 1

COC	Groundwater Exposure Concentration (mg/L)	Indoor Air Exposure Concentration (mg/m3)	Indoor Air RGO (mg/m3)		Groundwater Concentration Resulting in Indoor Air RGO (mg/L)		MCL (a) (mg/L)	Does Groundwater Exposure Concentration Exceed Indicated Criterion?		
			Carcinogenic	Noncarcinogenic	Carcinogenic	Noncarcinogenic		Risk-based RGO	HI-based RGO	MCL
Current Worker Cumulative risk and HI for this receptor do not exceed target values.										
Future Worker										
Carbon tetrachloride	1.20E-01	1.19E-02	2.70E-04	2.90E-03	2.73E-03	2.93E-02	5.00E-03	Yes	Yes	Yes
Chloroform	6.00E-02	9.48E-04	1.76E-04	--	1.11E-02	--	1.00E-01 (b)	Yes	--	No
Dichloroethene, 1,1-	1.40E-01	2.91E-02	7.86E-05	--	3.78E-04	--	7.00E-03	Yes	--	Yes
Tetrachloroethene	1.55E-01	1.88E-02	7.23E-03	--	5.96E-02	--	5.00E-03	Yes	--	Yes
Trichloroethene	1.37E+00	6.63E-02	2.37E-03	--	4.89E-02	--	5.00E-03	Yes	--	Yes
Vinyl chloride	3.40E-02	2.09E-02	4.75E-05	--	7.73E-05	--	2.00E-03	Yes	--	Yes
Future Residential										
Carbon tetrachloride	1.20E-01	1.19E-02	1.80E-04	5.67E-04 *	1.82E-03	5.71E-03 *	5.00E-03	Yes	Yes	Yes
Chloroform	6.00E-02	9.48E-04	1.17E-04	--	7.41E-03	--	1.00E-01 (b)	Yes	--	No
Dichloroethane, 1,1-	5.40E-02	1.41E-02	NC	1.41E-01 *	NC	5.40E-01 *	ND	NC	No (c)	ND
Dichloroethene, 1,1-	1.40E-01	2.91E-02	5.29E-05	--	2.55E-04	--	7.00E-03	Yes	--	Yes
Tetrachloroethene	1.55E-01	1.88E-02	4.70E-03	--	3.88E-02	--	5.00E-03	Yes	--	Yes
Trichloroethane, 1,1,1-	1.10E+00	8.25E-02	NC	2.84E-01 *	NC	3.79E+00 *	2.00E-01	NC	No (c)	Yes
Trichloroethene	1.37E+00	6.63E-02	1.58E-03	--	3.26E-02	--	5.00E-03	Yes	--	Yes
Vinyl chloride	3.40E-02	2.09E-02	3.17E-05	--	5.15E-05	--	2.00E-03	Yes	--	Yes

Note: -- = does not contribute an HI of at least 0.1.

NC = noncarcinogenic.

ND = not determined.

(a) Site groundwater is not potable due to salinity; MCLs are provided for comparison only.

(b) MCL for total trihalomethanes.

(c)  $0.1 < HQ < 1$ , but the cumulative HI for the medium is  $> 1$ .

\* Based on residential child exposure.

Source: ESE.

[C:\PUM\RA3\H-ROGOW\WQ1\doc\07May10]

Table 6-12. COPCs for the ERA and Media in Which Detected/Modeled (Page 1 of 2)

Chemical	Soil	Sediment	Groundwater	Surface Water
<b>IOCs</b>				
Antimony	-	G	E	G
Arsenic	M,S	G	E,S	G
Barium	S	G	E,S	G
Beryllium	-	G	E	G
Cadmium	-	G	E,S	G
Chromium	-	G	E	G
Copper	M,S	G	E	G
Iron	S	G	S	G
Lead	M,S	G	E,S	G
Manganese	-	G	S	G
Mercury	-	G	E	G
Nickel	-	G	E	G
Selenium	-	G	E	G
Silver	-	G	E	G
Thallium	M	G	S	G
Vanadium	S	-	-	-
Zinc	M,S	G	E,S	G
<b>Munitions/Nitroaromatic Compounds</b>				
Dinitrotoluene, 2,4-	M	-	-	-
Nitrosodi-n-propylamine, N-	M	-	-	-
<b>PAHs</b>				
Acenaphthene	M	-	-	-
Benz(a)anthracene	M,S	-	-	-
Benzo(a)pyrene	S	-	-	-
Benzo(b)fluoranthene	S	-	-	-
Benzo(ghi)perylene	S	-	-	-
Benzo(k)fluoranthene	S	-	-	-
Chrysene	M,S	-	-	-
Fluoranthene	M,S	-	-	-
Indeno(1,2,3-cd)pyrene	S	-	-	-
Phenanthrene	M,S	-	-	-
Pyrene	S	-	-	-
<b>Pesticides</b>				
Aldrin	S	-	-	-
BHC, beta-	S	-	-	-
BHC, delta-	S	-	-	-
Chlordane, alpha-	S	-	-	-
Chlordane, gamma-	S	-	-	-
DDD, p,p'-	M,S	-	-	-
DDE, p,p'-	M,S	-	-	-
DDT, p,p'-	M	-	-	-
Endosulfan sulfate	M	-	-	-
Lindane	S	-	-	-



Table 6-12. COPCs for the ERA and Media in Which Detected/Modeled (Page 2 of 2)

Chemical	Soil	Sediment	Groundwater	Surface Water
SVOCs, Miscellaneous				
Bis(2-ethylhexyl) phthalate	S	-	S	G
Butylbenzyl phthalate	M	-	-	-
Di-n-butyl phthalate	M	-	-	-
Dichlorobenzene, 1,4-	M	-	-	-
Dimethylphenol, 2,4-	M	-	-	-
Phenol	M,S	-	-	-
Trichlorobenzene, 1,2,4-	M	-	-	-
VOCs, Miscellaneous				
Acetone	E	-	E	G
Benzene	E	-	-	-
Bromodichloromethane	-	-	E	G
Carbon tetrachloride	-	-	E	G
Chloroform	-	-	E	G
Dichloroethane, 1,1-	-	-	E,S	G
Dichloroethene, 1,1-	E	-	E	G
Dichloroethene, 1,2-	E	-	E,S	G
Methylene chloride	E	-	E	G
Tetrachloroethene	E,S	-	E,S	G
Toluene	E,S	-	-	-
Trichloroethane, 1,1,1-	E	-	E	G
Trichloroethene	-	-	E,S	G
Vinyl chloride	-	-	E	G
Xylenes	E	-	-	-

Note: E = COPC detected in previous ESE samples from the designated medium.  
 G = COPC modeled from groundwater into the designated medium by ESE.  
 M = COPC detected in the designated medium by Malcolm Pirnie.  
 S = COPC detected in 1995 ESE samples from the designated medium.  
 - = not applicable for this medium.

Source: ESE.

{QDRUM-RA3/V-COPCE.TBL/dbc/07May96}

Table 6-13. Ecological Evaluations of Surface Water/Sediment Contamination Issues

Ecological Endpoint	Medium	Derivation of Benchmarks	COPCs Evaluated	Exposure Concentration Development
Aquatic Organisms - 10 <sup>th</sup> percentile LOAEL	Sediment	NOAA, 1990	Metals	Modelled from GW
Aquatic Organisms - Acute AWQCs	Surface Water	Federal and State AWQCs	Metals, SVOC, VOCs	UCL <sub>95</sub> GW concentrations
Aquatic Organisms - Chronic AWQCs	Surface Water	Federal and State AWQCs	Metals, SVOC, VOCs	SW concentration modelled from GW UCL <sub>95</sub> values
Great Blue Heron - estimated NOAEL level	Contaminated fish supply	Literature Search	Metals, SVOC, VOCs	BCF factors applied to modelled SW concentrations

Source: ESE.

{QDRUM-RA3/V-ECOMTH.TBL/dbc/07May96}

Table 6-14. Intake Parameters for the Great Blue Heron

Species	Intake Medium	Intake (kg/kg-BW/day)	Exposure Factors			Source / Comments
Great Blue Heron	Fish	1E-02	IRf	0.396	kg/day	Stalmaster, 1987
			DFf	0.7		Conservative estimate based on bald eagle
			Fif	0.1		Conservative estimate
			EF	365	days/year	Worst-case estimate
			ED	30	years	Lifespan for the bald eagle (Stalmaster, 1987)
			BW	2.2	kg	EPA, 1993b
			AT	10950	days	ED * 365 days/year

Source: ESE.

{QDRUM-RA3/H-INTAKE.WQ1/dbc/08May96}

Table 6-15. Chemical Intakes for the Great Blue Heron

COPC	Cgw (mg/L)	Csw (mg/L)	BCF (L/kg)	Cf (mg/kg)	Chemical Intake * (mg/kg/day)
Acetone	1.30E+00	3.08E-07	6.90E-01 (a,b)	2.13E-07	2.13E-09
Antimony	5.20E-02	1.23E-08	1.00E+00 (c)	1.23E-08	1.23E-10
Arsenic	1.20E-01	2.84E-08	4.40E+01 (c)	1.25E-06	1.25E-08
Barium	1.73E-01	4.10E-08	1.00E+01 (d)	4.10E-07	4.10E-09
Beryllium	5.00E-03	1.19E-09	1.90E+01 (c)	2.25E-08	2.25E-10
Bis(2-ethylhexyl)phthalate	5.40E-02	1.28E-08	6.16E+02 (a,e)	7.88E-06	7.88E-08
Bromodichloromethane	1.20E-01	2.84E-08	2.30E+01 (a)	6.54E-07	6.54E-09
Cadmium	1.50E-02	3.56E-09	8.10E+01 (c)	2.88E-07	2.88E-09
Carbon tetrachloride	1.20E-01	2.84E-08	1.90E+01 (c)	5.40E-07	5.40E-09
Chloroform	6.00E-02	1.42E-08	3.75E+00 (c)	5.33E-08	5.33E-10
Chromium	2.06E-01	4.88E-08	1.60E+01 (c)	7.81E-07	7.81E-09
Copper	5.50E-02	1.30E-08	2.00E+02 (c)	2.61E-06	2.61E-08
Dichloroethane, 1,1-	5.40E-01	1.28E-07	1.30E+00 (a)	1.66E-07	1.66E-09
Dichloroethene, 1,1-	1.40E-01	3.32E-08	5.60E+00 (c)	1.86E-07	1.86E-09
Dichloroethenes, 1,2-, total	5.00E-01	1.19E-07	1.60E+00 (c)	1.90E-07	1.90E-09
Iron	7.79E+00	1.85E-06	na	nc	nc
Lead	1.02E-01	2.42E-08	4.90E+01 (c)	1.18E-06	1.18E-08
Manganese	2.73E+00	6.47E-07	na	nc	nc
Mercury	3.00E-04	7.11E-11	5.50E+03 (c)	3.91E-07	3.91E-09
Methylene chloride	9.00E-03	2.13E-09	5.00E+00 (c)	1.07E-08	1.07E-10
Nickel	8.70E-02	2.06E-08	4.70E+01 (c)	9.69E-07	9.69E-09
Selenium	9.00E-02	2.13E-08	1.60E+01 (c)	3.41E-07	3.41E-09
Silver	1.20E-02	2.84E-09	3.08E+03 (c)	8.76E-06	8.76E-08
Tetrachloroethene	1.55E-01	3.67E-08	3.10E+01 (c)	1.14E-06	1.14E-08
Thallium	5.50E-03	1.30E-09	2.60E+02 (a,f)	3.39E-07	3.39E-09
Trichloroethane, 1,1,1-	1.10E+00	2.61E-07	5.60E+00 (c)	1.46E-06	1.46E-08
Trichloroethene	1.37E+00	3.25E-07	1.06E+01 (c)	3.44E-06	3.44E-08
Vinyl chloride	3.40E-02	8.06E-09	1.17E+00 (c)	9.43E-09	9.43E-11
Zinc	4.16E-01	9.86E-08	4.70E+01 (c)	4.63E-06	4.63E-08

Note: BCF = bioconcentration factor.

Cf = chemical concentration in fish = Csw \* BCF.

Cgw = chemical concentration in groundwater (Appendix J, Table J-2).

Csw = chemical concentration in surface water = Cgw \* dilution factor (2.37E-07).

(a) Hazardous Substances Data Bank (HSDB), 1996.

(b) Based on a single static test with haddock.

(c) EPA Superfund Public Health Evaluation Manual (SPHEM), 1986d.

(d) Oil and Hazardous Materials/Technical Assistance Data System (OHM/TADS), 1996.

(e) Average value for several freshwater species.

(f) Average value of muscle, liver, and gills for the Atlantic salmon.

\* Chemical Intake = Fish Intake (Table 6-14) \* Cf.

Source: ESE.

Table 6-16. Ecotoxicity Benchmark Values for the Great Blue Heron (Page 1 of 7)

COPC	Study Organism (Common Name)	Study Organism (Scientific Name)	Test	Endpoint *	Conc.	Units	Reference
Acetone	Dog	Unspecified		LDLo	8.00E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Mouse	Unspecified		LD50	3.00E+03	mg/kg	PCJ, 1980 (RTECS, TOMES Vol. 29, 1996)
	a Pheasant, Ring-Necked	<i>Phasianus colchicus</i>		LC50	> 4.00E+04	ppm	USFWS, 1975 (HSDB, TOMES Vol. 29, 1996)
	a Quail, Japanese	<i>Coturnix coturnix japonica</i>		LC50	> 4.00E+04	ppm	USFWS, 1986 (HSDB, TOMES Vol. 29, 1996)
	Rabbit	Unspecified		LD50	5.34E+03	mg/kg	FAO, 1970 (RTECS, TOMES Vol. 29, 1996)
	Rat	Unspecified		LD50	5.80E+03	mg/kg	JTEH, 1985 (RTECS, TOMES Vol. 29, 1996)
	a Bird Average	Various		LC50	> 4.00E+04	ppm	
Antimony	Rat	Unspecified	Acute	LD50	7.00E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Chronic	LOAEL	3.50E-01	mg/kg/day	IRIS, TOMES Vol. 29, 1996
Arsenic	Chicken	Unspecified		LDLo	1.50E+01	mg/kg/day	Hatch, 1977
	Chicken	Unspecified		LDLo	2.30E+00	mg/kg/day	Hatch, 1977
	Deer, White-tailed	<i>Odocoileus virginianus</i>		TD	3.40E+01	mg/kg-bw	USFWS, 1988
	Duck, Mallard	<i>Anas platyrhynchos</i>	Acute	LD50	5.00E+02	mg/kg-bw	USFWS, 1988
	Duckling	Unspecified	Subchronic	LOAEL	1.89E+01	mg/kg/day	ESE, 1989
	Horse	Unspecified	Chronic	NOEL	1.30E+00	mg/kg/day	Radeleff, 1970
	Mouse	Unspecified	Acute	LD50	1.60E+00	mg/kg/day	Gough et al., 1979
	Mouse	Unspecified	Acute	LOEC	4.00E+01	mg/kg-bw/day	EPA, HEA, 1984
	Rabbit, Wild	<i>Sylvilagus sp.</i>			1.05E+01	mg/kg-bw	USFWS, 1988
Barium	Dog	Unspecified	Acute	LLD	9.00E+01	mg/kg-bw	RTECS, TOMES Vol. 29, 1996
	Guinea pig	Unspecified	Acute	LLD	7.60E+01	mg/kg-bw	RTECS, TOMES Vol. 29, 1996
	Mouse	Unspecified	Acute	LLD	7.00E+01	mg/kg-bw	RTECS, TOMES Vol. 29, 1996
	Rabbit	Unspecified	Acute	LLD	1.70E+02	mg/kg-bw	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Acute	LD50	1.18E+02	mg/kg-bw	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Acute	LD50	4.18E+02	mg/kg-bw	RTECS, TOMES Vol. 29, 1996
Beryllium	Rat	Unspecified	Chronic	NOAEL	5.40E-01	mg/kg/day	IRIS, TOMES Vol. 29, 1996

Table 6-16. Ecotoxicity Benchmark Values for the Great Blue Heron (Page 2 of 7)

COPC	Study Organism (Common Name)	Study Organism (Scientific Name)	Test	Endpoint *	Conc.	Units	Reference
Bis(2-ethylhexyl) phthalate	Guinea pig	Unspecified	Acute	LD50	2.63E+04	mg/kg	Krauskopf, 1973
	b Mouse	Unspecified	Acute	LD50	4.90E+04	mg/kg	Yamada, 1974
	b Mouse	Unspecified	Acute	LD50	2.60E+04	mg/kg	Patty, 1967
	b Mouse	Unspecified	Acute	LD50	3.35E+04	mg/kg	Krauskopf, 1973
	Rabbit	Unspecified	Acute	LD50	3.39E+04	mg/kg	Shaffer et al., 1945
	Rat	Unspecified	Acute	LD50	2.60E+04	mg/kg	Patty, 1967
	Rat, Wistar (male)		Acute	LD50	> 3.40E+04	mg/kg	Hodge, 1943
	Rat, Wistar (male)		Acute	LD50	3.06E+04	mg/kg	Shaffer et al., 1945
	b Mouse Average	Unspecified	Acute	LD50	3.62E+04	mg/kg	
Bromodichloromethane	Mouse	Unspecified	Acute	LD50	4.50E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	Mouse	Unspecified	Chronic	LOAEL	1.79E+01	mg/kg/day	IRIS, TOMES Vol. 29, 1996
	Rat	Unspecified	Acute	LD50	4.30E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
Cadmium	Mouse	Unspecified	Acute	LD50	8.90E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	Quail, Japanese	<i>Coturnix coturnix japonica</i>	Chronic	LOEL	7.50E+01	mg/kg	Richardson et al., 1974 (ECOTOX, 1995)
	Rabbit	Unspecified	Acute	LDLo	7.00E+01	mg/kg	RTECS, TOMES Vol. 29, 1996
Carbon tetrachloride	Rat	Unspecified	Subchronic	NOAEL	7.10E-01	mg/kg/day	IRIS, TOMES Vol. 29, 1996
Chloroform	Dog	Unspecified	Acute	LD50	2.25E+03	mg/kg	HSDB, TOMES Vol. 29, 1996
	Dog	Unspecified	Acute	LDLo	1.00E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Dog	Unspecified	Chronic	LOAEL	1.29E+01	mg/kg/day	IRIS, TOMES Vol. 29, 1996
	Guinea pig	Unspecified	Acute	LD50	8.20E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	Mouse	Unspecified	Acute	LD50	3.60E+01	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rabbit	Unspecified	Acute	LD50	9.83E+03	mg/kg	HSDB, TOMES Vol. 29, 1996
	Rabbit	Unspecified	Acute	LDLo	5.00E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Acute	LD50	9.08E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat, white	Unspecified	Acute	LD50	2.18E+03	mg/kg	HSDB, TOMES Vol. 29, 1996

Table 6-16. Ecotoxicity Benchmark Values for the Great Blue Heron (Page 3 of 7)

COPC	Study Organism (Common Name)	Study Organism (Scientific Name)	Test	Endpoint *	Conc.	Units	Reference
Chromium III	Duck, Black	<i>Anas rubripes</i>	Acute	NOAEL	1.00E+02	ppm	USFWS, 1986
	Rat	Unspecified	Chronic	NOEL	1.47E+03	mg/kg/day	IRIS, TOMES Vol. 29, 1996
Chromium VI	Rat	Unspecified	Chronic	NOAEL	2.40E+00	mg/kg/day	IRIS, TOMES Vol. 29, 1996
Copper	Lamb	Unspecified		Death	2.70E+01	mg/kg	Tait et al., 1971
	Lamb	Unspecified	Acute	Death	9.00E+00	mg/L	Nilson, 1968
	Lamb	Unspecified	Acute	Death	2.70E+01	mg/kg	Tait et al., 1971
	Mouse	Unspecified	Chronic	LOAEL	4.25E+01	mg/kg/day	Massie and Aiello, 1984 (ATSDR, 1984)
	Pheasant		Acute	LC50	7.67E+02	mg/kg	Wito Working Group, 1992 (Toxline, 1995)
	Rat	Unspecified		NOEC	8.00E+01	mg/kg-bw/day	EPA, 1984
	Rat	Unspecified	Acute	NOAEL	2.50E+02	mg/kg/day	Haywood, 1985 (ATSDR, 1990)
	Rat	Unspecified	Subchronic	NOAEL	1.30E+02	mg/kg/day	Llewellyn, 1985 (ASTDR, 1990)
	Sheep	Unspecified	Acute	Death	2.00E+02	mg/kg-bw	Osweiler et al., 1985
	Sheep	Unspecified	Chronic		1.50E+00	g/day	Clement et al., 1985
	Swine	Unspecified	Chronic		2.60E+00	mg/kg-bw/day	USATHAMA, 1989
	Swine	Unspecified	Chronic		2.50E+02	mg/kg	USATHAMA, 1989
Dichloroethane, 1,1-	c Rat	Unspecified	Acute	LD50	1.41E+04	mg/kg	HSDB, TOMES Vol. 29, 1996
	c Rat	Unspecified	Acute	LD50	7.25E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	c Rat Average	Unspecified	Acute	LD50	7.41E+03		
Dichloroethene, 1,1-	Dog	Unspecified	Acute	LDLo	5.75E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Mouse	Unspecified	Acute	LD50	1.94E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Acute	LD50	2.00E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Acute	LD50	1.50E+03	mg/kg	HSDB, TOMES Vol. 29, 1996
	Rat	Unspecified	Chronic	LOAEL	9.00E+00	mg/kg/day	IRIS, TOMES Vol. 29, 1996
Dichloroethene, 1,2-	Rat	Unspecified	Acute	LD50	7.70E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
Iron	Guinea Pig	Unspecified	Acute	LD50	2.00E+04	mg/kg	RTECS, TOMES Vol. 29, 1996
	d Guinea Pig	Unspecified	Subchronic	LD50	1.20E+03	mg/kg	EPA, 1984c
	Guinea pig	Unspecified	Acute	LD50	2.00E+04	mg/kg	RTECS, TOMES Vol. 29, 1996
	d Mouse	Unspecified	Subchronic	LD50	9.79E+02	mg/kg	EPA, 1984c

Table 6-16. Ecotoxicity Benchmark Values for the Great Blue Heron (Page 4 of 7)

COPC	Study Organism (Common Name)	Study Organism (Scientific Name)	Test	Endpoint *	Conc.	Units	Reference
Iron, cont.	Rat	Unspecified	Acute	LD50	3.00E+04	mg/kg	RTECS, TOMES Vol. 29, 1996
	d Rat	Unspecified	Subchronic	LD50	3.19E+02	mg/kg	EPA, 1984c
	d Rat	Unspecified	Subchronic	LD50	4.00E+03	mg/kg	EPA, 1984c
	d Mammal Average	Various	Subchronic	LD50	1.62E+03	mg/kg	
Lead	Cow (calf)	Unspecified	Chronic	Death	6.30E+02	mg/kg-bw	Dollahite et al., 1978
	Cow (calf)	Unspecified	Chronic	Death	3.20E+01	mg/kg-bw	Dollahite et al., 1978
	Dog	Unspecified	Chronic		2.94E+02	mg/kg-bw	Clark, 1979
	Dove, Mourning	<i>Zenaida macroura</i>	Chronic		7.20E+01	mg/kg	Buerger et al., 1986
	Duck, Mallard	<i>Anas platyrhynchos</i>		LD50	1.07E+02	mg/kg-bw	
	Horse	Unspecified	Chronic	Death	6.56E+02	mg/kg-bw	Dollahite et al., 1978
	Horse	Unspecified	Chronic	Death	6.21E+02	mg/kg-bw	Burrows and Borchard, 1982
	Horse	Unspecified	Chronic	Death	1.13E+03	mg/kg-bw	Burrows and Borchard, 1982
	Kestrel, American	<i>Falco sparverius</i>	Chronic		7.50E+02	mg/kg-bw	Hoffman et al., 1985
	Mouse	Unspecified	Chronic		6.60E+00	mg/kg-bw	Clark, 1979
	Quail, Japanese	<i>Coturnix coturnix japonica</i>	Chronic	LC50	5.00E+03	ppm	HSDB, TOMES Vol. 29, 1996
	Sheep	Unspecified	Chronic	NOEC	2.25E+02	mg/kg-bw	NRCC, 1973; Forbes and Sanderson, 1978
Manganese	Rat	Unspecified	Acute	LD50	9.00E+03	mg/kg	RECS, 1994
Mercury	Quail, Japanese	<i>Coturnix coturnix japonica</i>	Acute	LD50	3.11E+01	mg/kg	Hill and Soares, 1984
	Rat	Unspecified	Chronic	NOAEL	3.20E-01	mg/kg/day	Fitzhugh et al., 1950 (ATSDR, 1989)
Methylene chloride	e Mouse	Unspecified	Chronic	LOEL	5.80E+02	mg/kg	Kirschman et al., 1986
	Rat	Unspecified	Acute	LD50	1.60E+03	mg/kg	Verschueren, 1983
	e Rat	Unspecified	Chronic	LOEL	1.90E+02	mg/kg	Kirschman et al., 1986
	e Mammal Average	Various	Chronic	LOEL	3.85E+02	mg/kg	
Nickel	Dog	Unspecified	Chronic		6.30E+01	mg/kg	
	Guinea pig	Unspecified		LDLo	5.00E+00	mg/kg-bw	OHM/TADS, TOMES Vol. 29, 1996



Table 6-16. Ecotoxicity Benchmark Values for the Great Blue Heron (Page 5 of 7)

COPC	Study Organism (Common Name)	Study Organism (Scientific Name)	Test	Endpoint *	Conc.	Units	Reference
Nickel, cont.	Rat	Unspecified		LOEL	5.00E+01	mg/kg-bw	Ambrose et al., 1976
	Rat	Unspecified	Chronic		2.00E+01	mg/kg-bw	Nation et al., 1985
	Rat	Unspecified	Chronic	NOEL	5.00E+00	mg/kg-bw	Ambrose et al., 1976
Selenium	Chicken	Unspecified	Acute		7.00E+00	ppm	Latshaw, 1978 (USFWS, 1985)
	Cow	Unspecified		MLD	4.50E+00	mg/kg	OHM/TADS, TOMES Vol. 29, 1996
	Cow	Unspecified	Acute	Death	1.10E+01	mg/kg/day	USFWS, 1984
	Cow	Unspecified	Acute	LD50	2.00E+00	mg/kg	OHM/TADS, TOMES Vol. 29, 1996
	Dog	Unspecified	Acute	LD50	4.00E+00	mg/kg	OHM/TADS, TOMES Vol. 29, 1996
	Duck, Mallard	Unspecified	Chronic	Death	1.00E+02	ppm	USFWS, 1985
	Hamster	Unspecified	Chronic	NOAEL	4.20E-01	mg/kg/day	Birt et al., 1986 (ATSDR, 1989e)
	Horse	Unspecified	Acute	Death	3.30E+00	mg/kg/day	USFWS, 1985
	Monkey	<i>Macaca irus</i>	Chronic	NOEL	2.00E-01	mg/kg/day	EPA, 1984d
	Pig	Unspecified	Acute	MLD	6.00E+00	mg/kg	OHM/TADS, TOMES Vol. 29, 1996
	Quail, Japanese	<i>Coturnix coturnix japonica</i>	Acute		6.00E+00	ppm	El-Bergearmi et al., 1977 (USFWS, 1985)
	Rat	Unspecified	Acute	Death	2.30E+01	ppm	ATSDR, 1989e
	Rat	Unspecified	Acute	LD50	6.70E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Chronic	NOAEL	3.00E-01	mg/kg/day	Tinsley et al., 1967 and Harr et al., 1967 (ATSDR, 1989e)
	Rat	Unspecified	Subchronic	NOEL	1.60E-01	mg/kg/day	EPA, 1984
	Sheep	Unspecified		Death	4.00E+02	ppm	EPA, 1985a
	Sheep	Unspecified	Acute	Death	3.20E+00	mg/kg/day	USFWS, 1985
	Swine	Unspecified	Acute	Death	1.50E+01	mg/kg/day	USFWS, 1984
	Swine	Unspecified	Chronic	>	5.00E+00	mg/kg	
Silver	No pertinent ecotoxicity benchmarks were located in the available literature.						
Tetrachloroethene	Cat	Unspecified	Acute	LDLo	4.00E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Dog	Unspecified	Acute	LDLo	4.00E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Mouse	Unspecified	Acute	LD50	8.10E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Mouse	Unspecified	Subchronic	LOAEL	7.10E+01	mg/kg/day	IRIS, TOMES Vol. 29, 1996
	Rabbit	Unspecified	Acute	LDLo	5.00E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Acute	LD50	2.63E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rat	Unspecified	Subchronic	NOAEL	1.40E+01	mg/kg/day	IRIS, TOMES Vol. 29, 1996

Table 6-16. Ecotoxicity Benchmark Values for the Great Blue Heron (Page 6 of 7)

COPC	Study Organism (Common Name)	Study Organism (Scientific Name)	Test	Endpoint *	Conc.	Units	Reference
Thallium	f Birds	Various	Chronic	LD	2.00E+01	mg/kg	OHM/TADS, TOMES Vol. 29, 1996
	f Chicks	Various	Chronic	LD	6.00E+00	mg/kg	OHM/TADS, TOMES Vol. 29, 1996
	Rat, rabbit, dog	Various	Acute	LD50	3.20E+01	mg/kg	OHM/TADS, TOMES Vol. 29, 1996
	Small mammals	Various	Acute	LD50	1.50E+01	mg/kg-bw	Stokinger, 1981; EPA, 1988
	f Bird Average	Various	Chronic	LD	1.30E+01	mg/kg	
Trichloroethane, 1,1,1-	Dog	Unspecified	Acute	LD50	7.50E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
	g Guinea pig	Unspecified	Acute	LD50	9.47E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	g Mouse	Unspecified	Acute	LD50	6.00E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	g Rabbit	Unspecified	Acute	LD50	5.66E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	g Rat	Unspecified	Acute	LD50	9.60E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	g Mammal Average	Various	Acute	LD50	7.68E+03	mg/kg	
Trichloroethene	Cat	Unspecified	Acute	LDLo	5.86E+03	mg/kg	Handbook Tox., 1959 (HSDB, TOMES Vol. 29, 1996)
	Dog	Unspecified	Acute	LD50	5.68E+03	mg/kg	WHO, 1985
	h Mouse	Unspecified	Acute	LD50	2.40E+03	mg/kg	RTECS, TOMES Vol. 29, 1996
	Rabbit	Unspecified	Acute	LDLo	7.33E+03	mg/kg	Handbook Tox., 1959 (HSDB, TOMES Vol. 29, 1996)
	h Rat	Unspecified	Acute	LD50	5.65E+03	mg/kg	JACT, 1992 (RTECS, TOMES Vol. 29, 1996)
	h Mammal Average	Various	Acute	LD50	4.02E+03	mg/kg	
Vinyl chloride	Rat	Unspecified	Acute	LD50	5.00E+02	mg/kg	RTECS, TOMES Vol. 29, 1996
Zinc	Cat	Unspecified	Subchronic	NOEL	7.64E+01	mg/kg/day	EPA, 1984e
	Cow	Unspecified		Death	2.00E+01	g/kg	EPA, 1985a
	Ferret	Unspecified	Acute	Death	3.00E+03	ppm	ATSDR, 1988c
	Ferret	Unspecified	Acute	LOAEL	8.50E+02	mg/kg/day	Straube et al., 1980 (ATSDR, 1988c)
	Mouse	Unspecified	Chronic	LOAEL	3.80E+01	mg/kg/day	ATSDR, 1988c
	Mouse	Unspecified	Subchronic	NOEL	1.88E+02	mg/kg/day	EPA, 1984e
	Pig	Unspecified	Acute	Death	> 2.00E+03	mg/kg	EPA, 1985a

Table 6-16. Ecotoxicity Benchmark Values for the Great Blue Heron (Page 7 of 7)

COPC	Study Organism (Common Name)	Study Organism (Scientific Name)	Test	Endpoint *	Conc. Units	Reference
Zinc, cont.	i Rat	Unspecified	Chronic	NOAEL	2.50E+02 mg/kg/day	EPA, 1984e
	i Rat	Unspecified	Chronic	NOAEL	1.25E+02 mg/kg/day	EPA, 1984e
	Rat	Unspecified	Subchronic	NOEL	9.50E+01 mg/kg/day	EPA, 1984e
	i Rat Average	Unspecified	Chronic	NOAEL	1.88E+02 mg/kg/day	

\* Endpoint: LC / LD = lethal concentration / dose.

Lo = lowest.

50 = fifty percent.

LOEC / LOEL = lowest observed effect concentration / level.

NOEC / NOEL = no observed effect concentration / level.

NOAEC / NOAEL = no observed adverse effect concentration / level.

TD = toxic dose.

a,b,c, etc. before a study organism indicates which benchmarks were averaged for a specific organism/group.

Source: ESE.

{QDRUM-PA3/H-BMHRN.WQ1/dbr/08May00}

Table 6-17. TRVs for the Great Blue Heron

COPC	Ecotoxicity Benchmark			UF (a)	TRV (b) (mg/kg/day)
	Value (mg/kg/day)	Study Organism (Common Name)	Test / Endpoint		
Acetone	4.00E+04	Bird Average	Acute LC50	1600	2.50E+01
Antimony	3.50E-01	Rat	Chronic LOAEL	80	4.38E-03
Arsenic	5.00E+02	Mallard Duck	Acute LD50	1600	3.13E-01
Barium	7.00E+01	Mouse	Acute LLD	1600	4.38E-02
Beryllium	5.40E-01	Rat	Chronic NOAEL	16	3.38E-02
Bis(2-ethylhexyl) phthalate	3.62E+04	Mouse Average	Acute LD50	1600	2.26E+01
Bromodichloromethane	1.79E+01	Mouse	Chronic LOAEL	80	2.24E-01
Cadmium	7.50E+01	Japanese Quail	Chronic LOEL	80	9.38E-01
Carbon tetrachloride	7.10E-01	Rat	Subchronic NOAEL	160	4.44E-03
Chloroform	1.29E+01	Dog	Chronic LOAEL	80	1.61E-01
Chromium	1.00E+02	Black Duck	Acute NOAEL	480	2.08E-01
Copper	7.67E+02	Pheasant	Acute LC50	1600	4.79E-01
Dichloroethane, 1,1-	7.41E+03	Rat Average	Acute LD50	1600	4.63E+00
Dichloroethene, 1,1-	9.00E+00	Rat	Chronic LOAEL	80	1.13E-01
Dichloroethenes, 1,2-, total	7.70E+02	Rat	Acute LD50	1600	4.81E-01
Iron	1.62E+03	Mammal Average	Subchronic LD50	1600	1.01E+00
Lead	7.50E+02	American Kestrel	Chronic Unknown	800	9.38E-01
Manganese	3.00E+03	Mouse	Acute LD50	1600	1.88E+00
Mercury	3.10E+01	Japanese Quail	Acute LD50	1600	1.94E-02
Methylene chloride	3.85E+02	Mammal Average	Chronic LOEL	80	4.81E+00
Nickel	5.00E+00	Rat	Chronic NOEL	16	3.13E-01
Selenium	1.00E+02	Mallard Duck	Chronic LD	800	1.25E-01
Silver	na	na	na	na	nc
Tetrachloroethene	1.40E+01	Rat	Subchronic NOAEL	160	8.75E-02
Thallium	1.30E+01	Bird Average	Chronic LD	800	1.63E-02
Trichloroethane, 1,1,1-	7.68E+03	Mammal Average	Acute LD50	1600	4.80E+00
Trichloroethene	4.02E+03	Mammal Average	Acute LD50	1600	2.51E+00
Vinyl chloride	5.00E+02	Rat	Acute LD50	1600	3.13E-01
Zinc	1.88E+02	Rat Average	Chronic NOAEL	16	1.18E+01

Not na = no pertinent toxicity information was located in available literature.

nc = TRV could not be calculated due to lack of an applicable benchmark.

(a) Uncertainty factors (UFs) are derived from Figure 6-1, Procedural Guidelines for Ecological Risk Assessments at U.S. Army Sites, USA, 1994.

(b) TRV = Ecotoxicity Benchmark Value (Table 6-16) / UF.

Source: ESE.

{QDRUM-RA3/V-TRVHRN.WQ1/dbc/07May98}

Table 6-18. EQs for the Great Blue Heron Based on Fish Ingestion

COPC	Chemical Intake (mg/kg/day)	TRV	EQ *
Acetone	2.13E-09	2.50E+01	9E-11
Antimony	1.23E-10	4.38E-03	3E-08
Arsenic	1.25E-08	3.13E-01	4E-08
Barium	4.10E-09	4.38E-02	9E-08
Beryllium	2.25E-10	3.38E-02	7E-09
Bis(2-ethylhexyl)phthalate	7.88E-08	2.26E+01	3E-09
Bromodichloromethane	6.54E-09	2.24E-01	3E-08
Cadmium	2.88E-09	9.38E-01	3E-09
Carbon tetrachloride	5.40E-09	4.44E-03	1E-06
Chloroform	5.33E-10	1.61E-01	3E-09
Chromium	7.81E-09	2.08E-01	4E-08
Copper	2.61E-08	4.79E-01	5E-08
Dichloroethane, 1,1-	1.66E-09	4.63E+00	4E-10
Dichloroethene, 1,1-	1.86E-09	1.13E-01	2E-08
Dichloroethenes, 1,2-, total	1.90E-09	4.81E-01	4E-09
Iron	nc	1.01E+00	--
Lead	1.18E-08	9.38E-01	1E-08
Manganese	nc	1.88E+00	--
Mercury	3.91E-09	1.94E-02	2E-07
Methylene chloride	1.07E-10	4.81E+00	2E-11
Nickel	9.69E-09	3.13E-01	3E-08
Selenium	3.41E-09	1.25E-01	3E-08
Silver	8.76E-08	na	--
Tetrachloroethene	1.14E-08	8.75E-02	1E-07
Thallium	3.39E-09	1.63E-02	2E-07
Trichloroethane, 1,1,1-	1.46E-08	4.80E+00	3E-09
Trichloroethene	3.44E-08	2.51E+00	1E-08
Vinyl chloride	9.43E-11	3.13E-01	3E-10
Zinc	4.63E-08	1.18E+01	4E-09

Note: na = no TRV is available for this chemical.  
nc = no chemical intake is calculated for this chemical.  
-- = EQ could not be calculated due to lack of a chemical intake or TRV.

\* EQ = Chemical Intake (Table 6-15) / TRV (Table 6-17)

Source: ESE.

{QDRUM-RA3/V-EQHRN.WQ1/dbc/08May96}

Table 6-19. Comparison of Surface Water Exposure Concentrations to Federal and State Water Quality Criteria \* (Page 1 of 2)

COPCs	Acute Surface Water Conc. (1)	Chronic Surface Water Conc. (2)	Protection of Freshwater Aquatic Life				Protection of Marine Aquatic Life				Acute Values Exceeding Suggested Acute ARARs?	Chronic Values Exceeding Suggested Chronic ARARs?
			Federal AWQC (3)		Virginia State WQS		Federal AWQC (3)		Virginia State WQS			
			Acute	Chronic	Acute	Chronic	Acute	Chronic	Acute	Chronic		
Acetone	1.30E+03	3.08E-04									--	--
Antimony	5.20E+01	1.23E-05	8.80E+01 p	3.00E+01 p			1.50E+03	5.00E+02			No	No
Arsenic	1.20E+02	2.84E-05	3.60E+02 a	1.90E+02 a	3.60E+02 a	1.90E+02 a	6.90E+01 a	3.60E+01 a	6.90E+01 a	3.60E+01 a	C,D	No
Barium	1.73E+02	4.10E-05									--	--
Beryllium	5.00E+00	1.19E-06	1.30E+02 b	5.30E+00 b							No	No
Bis(2-ethylhexyl) phthalate	5.40E+01	1.28E-05	9.40E+02 f	3.00E+00 f			2.94E+03 f	3.40E+00 f			No	No
Bromodichloromethane	1.20E+02	2.84E-05	1.10E+04 b,				1.20E+04 b,	6.40E+03 b,			No	No
Cadmium	1.50E+01	3.56E-06	3.90E+00 c	1.10E+00 c	3.90E+00 c	1.10E+00 c	4.30E+01	9.30E+00	4.30E+01	9.30E+00	A,B	No
Carbon tetrachloride	1.20E+02	2.84E-05	3.52E+04 b				5.00E+04 b				No	No
Chloroform	6.00E+01	1.42E-05	2.89E+04 b	1.24E+03 b							No	No
Chromium, total	2.06E+02	4.88E-05	1.60E+01 d	1.10E+01 d			1.10E+03 d	5.00E+01 d			A	No
Copper	5.50E+01	1.30E-05	1.80E+01 c	1.20E+01 c	1.77E+01 c	1.18E+01 c			2.90E+00	2.90E+00	A,B,D	No
Dichloroethane, 1,1-	5.40E+02	1.28E-04									--	--
Dichloroethene, 1,1-	1.40E+02	3.32E-05	1.13E+04 b,h				2.24E+05 b,h				No	No
Dichloroethenes, 1,2-, total	5.00E+02	1.19E-04	1.13E+04 b,h				2.24E+05 b,h				No	No
Iron	7.79E+03	1.85E-03		1.00E+03							--	No
Lead	1.02E+02	2.42E-05	8.20E+01 c	3.20E+00 c	8.16E+01 c	3.18E+00 c	1.40E+02	5.60E+00	7.50E+01	8.30E+00	A,B,D	No
Manganese	2.73E+03	6.47E-04									--	--
Mercury	3.00E-01	7.11E-08	2.40E+00	1.20E-02	2.40E+00	1.20E-02	2.10E+00	2.50E-02	2.10E+00	2.50E-02	No	No
Methylene chloride	9.00E+00	2.13E-06	1.10E+04 b,h				1.20E+04 b,	6.40E+03 b,			No	No
Nickel	8.70E+01	2.06E-05	1.40E+03 e	1.60E+02 e	1.42E+03 c	1.58E+02 c	7.50E+01 e	8.30E+00 e	7.50E+01	8.30E+00	C,D	No
Selenium	9.00E+01	2.13E-05	2.00E+01	5.00E+00	2.00E+01	5.00E+00	3.00E+02	7.10E+01	3.00E+02	7.10E+01	A,B	No
Silver	1.20E+01	2.84E-06	9.20E-01 d	1.20E-01	4.06E+00 c		7.20E+00	9.20E-01	2.30E+00		A,B,C,D	No
Tetrachloroethene	1.55E+02	3.67E-05	5.28E+03 b	8.40E+02 b			1.02E+04 b	4.50E+02 b			No	No
Thallium	5.50E+00	1.30E-06	1.40E+03 b	4.00E+01 b			2.13E+03 b				No	No
Trichloroethane, 1,1,1-	1.10E+03	2.61E-04	1.80E+04 b				3.12E+04 b				No	No
Trichloroethene	1.37E+03	3.25E-04	4.50E+04 b	2.19E+04 b			2.00E+03 b				No	No
Vinyl chloride	3.40E+01	8.06E-06									--	--
Zinc	4.16E+02	9.86E-05	1.20E+02 c	1.10E+02 c	1.17E+02 c	1.06E+02 c	9.50E+01	8.60E+01	9.50E+01	8.60E+01	A,B,C,D	No

Table 6-19. Comparison of Surface Water Exposure Concentrations to Federal and State Water Quality Criteria \* (Continued, Page 2 of 2)

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Note: AWQC = EPA ambient water quality criteria.

WQS = water quality standard.

LOEL = lowest observed effect level.

ug/L = micrograms per liter.

-- = no comparison can be made due to lack of federal and state criteria.

- (1) Assumes that surface water concentration at point of confluence is equivalent to groundwater concentration.
- (2) Modeled surface water concentration based on groundwater concentration and a surface water dilution factor (2.37E-7).
- (3) Values are from EPA's Integrated Risk Information System (IRIS, 1996), unless otherwise specified.
  - (a) Value for trivalent arsenic.
  - (b) Insufficient data are available to determine an AWQC; reported value is the LOEL.
  - (c) Hardness-dependent criteria assumes water hardness of 100 mg/L calcium carbonate.
  - (d) Value for the more toxic hexavalent chromium.
  - (e) Value for soluble nickel salts.
  - (f) Value for total phthalate esters.
  - (g) Value for total halomethanes.
  - (h) Value for total dichloroethenes.
  - (p) Proposed value.
- (A) Acute surface water exposure concentration exceeds Federal Acute AWQC for freshwater aquatic life.
- (B) Acute surface water exposure concentration exceeds Virginia State Acute WQS for freshwater aquatic life.
- (C) Acute surface water exposure concentration exceeds Federal Acute AWQC for marine aquatic life.
- (D) Acute surface water exposure concentration exceeds Virginia State Acute WQS for marine aquatic life.

\* All units are ug/L.

Source: ESE.

(CDPUM-PA3)H-SWCOMP.WQ1.doc(05May98)

Table 6-20. Comparison of Modeled Sediment Concentrations to NOAA Sediment Benchmark Values \*

COPCs	Cgw (mg/L)	Kd ** (L/kg)	Csed *** (mg/kg)	NOAA Sediment Benchmark (mg/kg)		Values Exceeding NOAA Benchmarks?
				ER-L	ER-M	
Antimony	5.20E-02	90	4.68E+00	2.0E+00	2.5E+01	L,M
Arsenic	1.20E-01	400	4.80E+01	3.3E+01	8.5E+01	L
Barium	1.73E-01	120	2.08E+01	ND	ND	--
Beryllium	5.00E-03	1300	6.50E+00	ND	ND	--
Cadmium	1.50E-02	13	1.95E-01	5.0E+00	9.0E+00	No
Chromium, total	2.06E-01	1700	3.50E+02	8.0E+01	1.5E+02	L,M
Copper	5.50E-02	70	3.85E+00	7.0E+01	3.9E+02	No
Iron	7.79E+00	50	3.90E+02	ND	ND	--
Lead	1.02E-01	1800	1.84E+02	3.5E+01	1.1E+02	L,M
Manganese	2.73E+00	130	3.55E+02	ND	ND	--
Mercury	3.00E-04	20	6.00E-03	1.5E-01	1.3E+00	No
Nickel	8.70E-02	300	2.61E+01	3.0E+01	5.0E+01	No
Selenium	9.00E-02	600	5.40E+01	ND	ND	--
Silver	1.20E-02	90	1.08E+00	1.0E+00	2.2E+00	L
Thallium	5.50E-03	3000	1.65E+01	ND	ND	--
Zinc	4.16E-01	80	3.33E+01	1.2E+02	2.7E+02	No

Note: Cgw = maximum chemical concentration detected in groundwater.  
Csed = chemical concentration in sediment.  
ER-L = exposure range--low; 10th percentile effect level.  
ER-M = exposure range--median; 50th percentile effect level.  
ND = not determined.  
-- = no comparison can be made due to lack of NOAA benchmarks.

(L) Sediment concentration exceeds ER-L.  
(M) Sediment concentration exceeds ER-M.

\* Only inorganics were evaluated because no NOAA values are available for volatile organics (NOAA, 1990).

\*\* Kd = Kd (Baes et al., 1984) \* 2 (see Section 6.2.3.3).

\*\*\* Csed = Cgw (Appendix J, Table J-2) \* Kd.

Source: ESE.

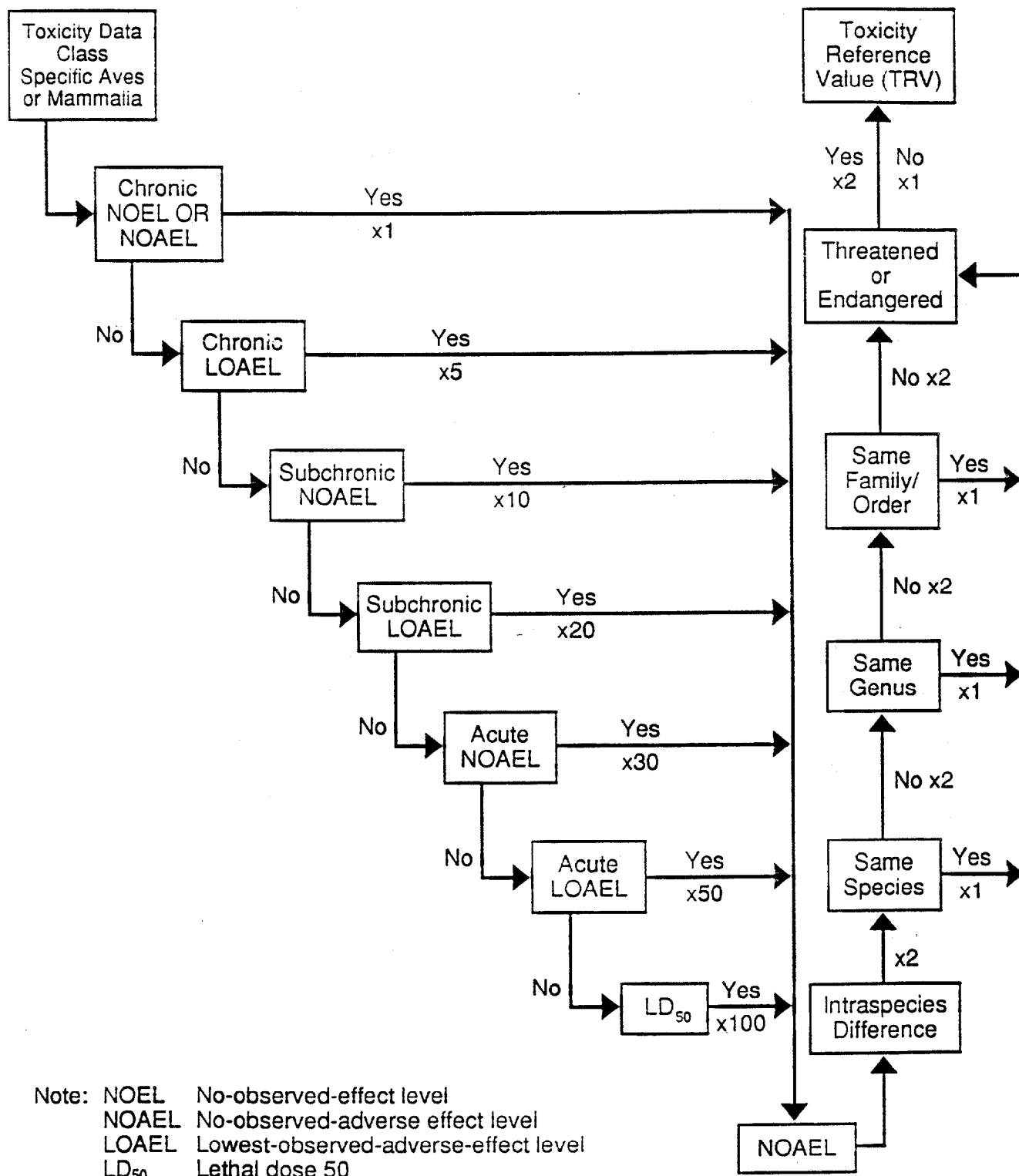


Table 6-21. Uncertainties in the ERA Process

ERA Component	Potential for Uncertainty
<p>COPC Selection</p>	<ul style="list-style-type: none"> <li>• Chemical monitoring data collected over time, analyzed by different laboratories, and evaluated using varying quality assurance methodology</li> <li>• Presence of tentatively identified compounds (TICs)</li> <li>• Current and future land uses</li> <li>• Lack of site-specific background data</li> </ul>
<p>Exposure Assessment</p>	<ul style="list-style-type: none"> <li>• Selection of terrestrial and aquatic indicator species</li> <li>• Selection of site-specific exposure pathways</li> <li>• Estimation of surface water and sediment concentrations without monitoring data</li> <li>• Estimation of exposure to multiple substances</li> <li>• Estimation of exposure parameters</li> </ul>
<p>Toxicity Assessment</p>	<ul style="list-style-type: none"> <li>• Selection of benchmark values</li> <li>• Uncertainty factors used in derivation of toxicity reference values (TRVs), including interspecies extrapolation</li> <li>• Interaction of multiple substances</li> </ul>
<p>Risk Characterization</p>	<ul style="list-style-type: none"> <li>• Evaluation of risks from multiple exposure pathways</li> <li>• Addition of risks from multiple substances</li> <li>• Use of generalized ambient water quality criteria (AWQCs) and water quality standards (WQSs) to evaluate risks to aquatic life</li> </ul>

Source: ESE.

{QDRUM-RA3/V-UNC RTE.TBL/dbc/08May96}



**Figure 6-1**  
**METHODOLOGY TO DERIVE TOXICITY REFERENCE**  
**VALUES (TRVs) FROM CLASS-SPECIFIC TOXICITY**  
**DATA**

SOURCE: U.S. ARMY (1994).

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## 7.0 SUMMARY

### 7.1 Summary

#### 7.1.1 Nature and Extent of Contamination

Soil sampling at the QADSY indicates VOC and TPH contamination; some small-scale SVOC, pesticide, and IOC contamination may also be present. The HM area appears to be the most affected by VOC contamination. However, contaminant-specific VOC concentrations were generally less than 100 µg/kg, and only one VOC was detected in the TCLP extracts. Although PCE was detected in two TCLP extracts, the concentrations were well below the TCLP standards.

Soil contamination by TPH is widespread in the TA, PPA, and HM area. Compressor oil is the reference standard most commonly matched by samples exhibiting TPH contamination. More than 50 percent of the samples collected from the TA, HM, and PPA exceed the VDEQ guidelines (100 ppm) for soil disposal to an industrial or sanitary landfill. Soil samples from deeper intervals (3-5 feet and 5-7 feet) were collected around known areas of TPH contamination to determine the vertical extent of contamination. TPH as diesel was detected in two borings (SB-5 and SB-6 in the northeast corner of the fenced area) but none of these detections exceeded the VDEQ 100 ppm disposal guidelines for TPH contamination.

The northern PPA and the TA appear to have levels of IOCs that are marginally higher than those noted in the background samples; however, all samples were below the applicable TCLP or RBC standard.

The TA appears to have low SVOC concentrations, although all samples were below RBCs. Pesticides detected at the QADSY were also below RBCs.

Surface soil contamination at the QADSY is sporadic, indicating that numerous one-time spills must have occurred throughout the history of the site. No correlation between surface soil staining and contamination is apparent.

Groundwater samples at the QADSY exhibited contamination by VOCs, TPH, and IOCs. A plume of contamination has formed beneath and downgradient (to the west and southwest) of the HM area. No VDEQ groundwater standards have been developed for VOCs. VDEQ nonpublic surface water supply standards were exceeded by TCE and PCE in well SW-2 and by carbon tetrachloride in wells SW-1 and SW-2. Acetone, 1,2-DCE, 1,1-DCE, 1,1-DCA, and TCA were also detected in groundwater samples; however, no VDEQ nonpublic water supply standards have been developed for these constituents.

Several VOCs were detected in deep well DW-1 at very low concentrations. All of these compounds were found in higher concentrations in the shallower nested well SW-2. None of

the VOCs for which VDEQ nonpublic water supply standards have been developed were exceeded by samples from the deep well. Analytical results indicate that the maximum depth of the contaminant plume may be approximately at the sampling interval in the deep wells. None of the wells installed in January 1993 had high concentrations of VOCs detected in them upon analysis.

An extensive hydropunch survey detected the presence of TCE and PCE adjacent to the seawall along the Elizabeth River and along the fence line in the northwest corner of the QADSY adjacent to the parking lot. Only two samples (HP-11-35 and HP-15-35) exceeded the VDEQ non-public water supply standards for TCE. The highest concentrations were noted at the 15-foot and 35-foot intervals, generally decreasing with increasing depth. The dispersal of high concentration readings throughout the study area suggests numerous contamination source points.

Although TPH was detected in six wells at the QADSY, only one sample exceeded the VDEQ groundwater standard of 1 ppm for TPH.

IOC contamination of the groundwater was indicated beneath the TA and the northwestern portion of the PPA during the initial stage of the RI investigation. VDEQ groundwater standards were exceeded for arsenic, cadmium, chromium, lead, mercury, and zinc in those areas. Subsequent sampling has shown low levels of IOCs present with the exception of SW-5, which exceeded the standard for mercury. No IOC standards were exceeded in the background well. Cadmium VDEQ groundwater standards were exceeded in May 1995 in DW-3, DW-5, DW-6, SW-9, and SW-10, but no other IOC standards were exceeded.

Bis(2-ethylhexyl)phthalate was estimated in DW-3 through DW-8 and SW-10 and also detected in SW-9.

Sediment samples were taken on 21 January 1993 from storm drainage conduits in the QADSY. The sediments do not exceed typical concentrations in soils in the eastern United States (Shacklett and Boerngen, 1984), or Federal Register Proposed Rules 20 May 1992 for concentration-based exemption criteria for hazardous waste listing, and Federal Register 27 July 1990, for corrective-action criteria.

TCL pesticide/PCB analysis revealed concentrations of the pesticides chlordane and DDT homologues (DDE, DDD). These pesticides were not detected previously in the TCLP analysis run on soil borings from the QADSY, suggesting that these contaminants may have originated in some other area of the base.

Both sediment samples were analyzed for TPH as gasoline and as diesel. TPH as diesel was detected at a level of 299 mg/kg in SD-1 and 58.3 mg/kg in SD-2. The sample from SD-1 exceeds the VDEQ 100 ppm action level.

### 7.1.2 Fate & Transport

Chemical fate/transport analysis summarizes the physical and chemical properties of the COPCs, the environmental fate processes potentially acting on the COPCs, and the contaminant migration pathways potentially associated with the COPCs. Although concentrations of site contaminants in soil and groundwater may be reduced by microbial degradation, volatilization, and photolysis, the environmental models used at this site indicate that the potential does exist for site chemicals to volatilize into site structures and migrate to surface water of the Elizabeth River.

### 7.1.3 Risk Assessment

An RA was generated in accordance with EPA region-wide and Region III guidance to assess the potential current and future human and ecological health risks associated with potential onsite exposures at the QADSY, assuming no remedial action is implemented at the site. The risk results are then used to develop remedial goal objectives (RGOs), goals which remedial alternatives strive to achieve considering other factors such as feasibility and achievability.

The RA identified the primary site-related COPCs at the QADSY. Based on past site operations and disposal activities at the site, the COPCs evaluated in the Human RA (HRA) and Ecological RA (ERA) include a subset of VOCs, SVOCs, and IOCs. The data used in the RA is taken from ESE sampling events (1990-1993) and sampling events from other contractors (Malcolm Pirnie, 1983-1986 and Baker Environmental, 1995). The most recent and/or reliable data are used in the calculation of the exposure concentrations for the RA. The number of chemicals to be evaluated in the RAs was reduced using 1) EPA Region III methodology for risk-based concentration screening, 2) comparison of site and background soil concentrations, and 3) a screening for nutritionally essential chemicals.

In addition, TPH was detected at the site. Although this group of chemicals is useful for determining the extent of petroleum-based contamination, a quantitative risk evaluation is not performed as TPH represents a large group of chemicals, typically composed of long, straight-chain hydrocarbons of relatively low toxicity. However, to provide a conservative risk evaluation, the carcinogenic PAHs were used as a surrogate to evaluate TPH.

The exposure assessment identifies significant human and ecological exposure pathways and population(s) based on the environmental fate/transport analysis; determines the exposure concentrations to potential receptors; and estimates the magnitude, duration, and frequency of exposure for each receptor (or receptor group). The primary exposure pathways evaluated in the HRA and ERA are as follows:

#### Human Exposure Pathways

- Current Worker -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

- Future Worker -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.
- Future Residential -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

#### Ecological Exposure Pathways

- Terrestrial -- ingestion of contaminated fish by great blue heron.
- Aquatic -- exposure to surrounding surface water and sediment by aquatic and benthic organisms.

Domestic groundwater consumption is an incomplete human exposure pathway as the water below the QADSY site is not potable due to the high salinity of the water. Thus, this pathway, under the guidance of State and Federal regulatory agencies, is not further evaluated in the RA. However, due to the presence of VOCs in groundwater beneath the site, inhalation of VOCs volatilized from groundwater into indoor air is evaluated.

The primary sources of toxicological data were from EPA-verified references. When an appropriate toxicological constant was not identified, current literature was reviewed to find appropriate toxicological data, which were used to calculate dose-response values using the methodologies outlined in EPA guidance documents.

The site-specific human carcinogenic and noncarcinogenic risk estimates are determined using the exposure concentrations and factors presented in the exposure assessment along with the dose-response information developed in the toxicity assessment. The potential carcinogenic risks are compared with the EPA target cumulative risk range of  $1 \times 10^{-6}$  (1 in 1,000,000) to  $1 \times 10^{-4}$  (1 in 10,000) [NCP, 40 Code of Federal Regulations (CFR) 300, 430:62].

When a cumulative carcinogenic risk (risk associated with exposure to a mixture of chemicals) to an individual receptor under the assumed exposure conditions at a Superfund site exceeds  $10^{-4}$ , CERCLA generally requires remedial action at the site (EPA, 1991d). If the cumulative risk is less than  $10^{-4}$ , action generally is not required but may be warranted if a chemical-specific standard that is risk based [e.g., the maximum contaminant level (MCL) or an ambient water quality criterion (AWQC)] is violated. A risk-based remedial decision could be superseded by the presence of noncarcinogenic impact or environmental impact at the site as indicated by a hazard index (HI) greater than 1 for human noncarcinogenic exposures or an exceedance of an ecotoxicity quotient (EQ) of 1 for aquatic or terrestrial exposures.

### Human Risk Characterization Results

The results of the HRA indicate that the following scenarios exceed either a cumulative risk of  $10^{-4}$  or an HI of 1:

Exposure Scenario	Medium	Exceedance	COCs
Future Worker	Indoor air	Risk > $1 \times 10^{-4}$	carbon tetrachloride, chloroform, 1,1-dichloroethene, tetrachloroethene, trichloroethene, and vinyl chloride
		HI > 1	carbon tetrachloride
Future Residential (Lifetime)	Indoor air	Risk > $1 \times 10^{-4}$	carbon tetrachloride, chloroform, 1,1-dichloroethane, 1,1-dichloroethene, tetrachloroethene, 1,1,1-trichloroethane, trichloroethene, vinyl chloride
(Child)	Indoor air	HI > 1	carbon tetrachloride, 1,1-dichloroethene, 1,1,1-trichloroethane
	Soil	HI > 1	thallium
(Adult)	Indoor Air	HI > 1	carbon tetrachloride

### Ecological Risk Characterization Results

Terrestrial--The EQs associated with exposure of great blue heron to site contaminants due to ingestion of fish are all less than 1, suggesting that there is low potential for adverse effects to the great blue heron due to site-related chemicals in fish caught near the site.

Aquatic--The EQs for water- and sediment-dwelling aquatic organisms at QADSY are all less than 1, indicating that there is low potential for adverse effects to these aquatic organisms.

### RGOs

The Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that remedial actions attain a degree of contaminant cleanup that ensures protection of public health and the

environment. Thus, the risk characterization results are used to identify whether site COPCs need to be reduced to acceptable health-based levels. The acceptable health-based levels are referred to as RGOs, which are chemical-specific concentration goals for individual chemicals for specific medium and reasonable land use combinations.

Based on the results of the risk characterization, future worker exposure to indoor air and future residential exposure to indoor air and soil resulted in a cumulative risk exceeding  $10^{-4}$  and/or an HI exceeding 1. However, to provide a complete site analysis, RGOs are developed for all chemicals contributing an individual risk of at least  $10^{-6}$  to a total of greater than  $10^{-4}$  or on HI of at least 0.1 to a total HI of greater than 1. In summary, RGOs are developed for the following chemicals to provide risk managers with the maximum risk-related media level options on which to develop remediation aspects of the Feasibility Study (FS):

Medium	Scenario	COCs	RGO
Groundwater	Future Worker	Carbon tetrachloride	2.7 $\mu\text{g/l}$
		chloroform	11.1 $\mu\text{g/l}$
		1,1-dichloroethene	0.38 $\mu\text{g/l}$
		tetrachloroethene	59.6 $\mu\text{g/l}$
		trichloroethene	48.9 $\mu\text{g/l}$
		vinyl chloride	0.08 $\mu\text{g/l}$
	Future Resident	Carbon tetrachloride	1.8 $\mu\text{g/l}$
		chloroform	7.4 $\mu\text{g/l}$
		1,1-dichloroethane	540 $\mu\text{g/l}$
		1,1-dichloroethene	0.26 $\mu\text{g/l}$
		tetrachloroethene	38.9 $\mu\text{g/l}$
		1,1,1-trichloroethane	3790 $\mu\text{g/l}$
		trichloroethene	32.6 $\mu\text{g/l}$
		vinyl chloride	0.05 $\mu\text{g/l}$
Soil	Future Resident	Thallium	12.5 mg/kg

## 7.2 Conclusions

### 7.2.1 Data limitations and Recommendations for Future Work

Data limitations indicate that some of the VOCs for the future worker and future resident RGOs have not been delineated in the groundwater. The recommended future work consists of delineating carbon tetrachloride, chloroform, 1,1-DCE, and vinyl chloride for the future worker. If the unlikelihood of the site becoming a residential area, the groundwater should also be delineated for 1,1-DCA and 1,1,1-TCA.



### 7.2.2 Recommended Remedial Action Objectives

The QADSY is located in a highly industrial area at the Norfolk Naval Base in Norfolk, Virginia. The future plans at the QADSY are to increase the fleet ship parking by paving the current five acre gravel area. There are no future building plans although the recommended remedial action objectives are for the RGOs for future worker. The future resident scenario is highly unlikely because of the location of the QADSY.

The QADSY was created by a fill operation as a disposal area for dredged materials excavated from the James River, Elizabeth River, and/or Willoughby Bay in the early 1950's. The dredged material has been recognized to contain elevated levels of PAHs and IOC contamination. There are no records where the dredged material came from or may be from numerous sources.

Background soil data was collected at a upgradient located adjacent to Bousch Creek. Background soil data indicated IOC data was within a order of magnitude from the highest concentration measured during the RI. The IOC impacted soil will be too complex to delineate because of the unknown source or sources of the dredged material. The IOC contamination appears to be inherited in the dredged material and not from the drum storage yard because of the measured IOCs levels are similar to background.

The recommended remedial action for soil is no action because the future plans are for the QADSY to be paved, subsequently terminating this ecologic risk pathway, and the IOC-impacted soil appears to be inherited from the dredged material that created Sewells Point.

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**REVISED DRAFT FINAL  
FEASIBILITY STUDY  
Q-Area Drum Storage Yard  
Norfolk Naval Base  
Norfolk, Virginia**

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## FS EXECUTIVE SUMMARY

This Feasibility Study (FS) report is based on the information presented in this document and the Remedial Investigation (RI) Report for the Q Area Drum Storage Yard (QADSY), Norfolk Naval Base, Norfolk, Virginia. The methodology in this FS report allows a step-by-step evaluation of technologies, alternatives, and assembled alternatives by progressing through a series of screenings.

### Identification and Screening of Remedial Technologies

Remedial technologies are identified and screened as follows:

- Develop remedial action objectives based on site characteristics, specifying the contaminants and media of interest.
- Identify general response actions for each medium of interest, defining remedial actions singly, or in combination, that may satisfy the remedial objectives and potential applicable or relevant and appropriate requirements (ARARs) for the QADSY.
- Identify and screen technology types and process options applicable to each general response action.

### Remedial Action Objectives and Goals

Specific remedial action objectives for the contaminated media are developed to satisfy the general objective of the National Contingency Plan to select a cost-effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment. Numerical remedial action goals are developed for groundwater and surface soil. The remedial action objective for groundwater is the adequate protection of public health from inhalation of volatile organic compounds (VOCs) in the groundwater extracted from the aquifer. The remedial action objective for surface soils at the site is to adequately protect public health and the environment.

### ARARs

The remedial alternatives developed in this FS are analyzed for compliance with federal and state ARARs. This process involves initially identifying potential requirements, evaluating the potential requirements for applicability or relevance and appropriateness, and determining the ability of the remedial alternatives to achieve the ARARs. ARARs can be divided into three groups: chemical-specific, location-specific and action-specific. Potential chemical- and action-specific ARARs are analyzed; no location-specific ARARs are identified for the QADSY.

## General Response Actions

General response actions are medium-specific groups of remedies identified for soil and groundwater. The majority will work in conjunction with other general response actions to meet all remedial action objectives. Available remedial action technologies and process options associated with each general response action are developed. In developing alternatives, combinations of general response actions are identified, and based on the RI, an initial determination is made of areas or volumes of contaminated groundwater and soil to which these general response action combinations might be applied. Contaminated groundwater volumes were calculated from the quantitative risk-based remedial goal objectives (RGOs) using the interpreted plume area.

No action for soil is relevant and appropriate at the QADSY because:

- IOCs contamination appear to be inherited from the dredged material.
- The QADSY is not conducive to an ecological environment because it is in a highly industrial area and is mostly a paved parking lot.
- The future plans are for the unpaved area to be paved, which will subsequently eliminate this ecologic risk pathway.

## Identifying and Screening Technology Types and Process Options

Preliminary identification and screening of the remedial technology types and technology process options produces a condensed list of applicable remedial action technologies along with their corresponding process options that may be assembled into suitable alternatives. Applicability of each technology was evaluated by reviewing its potential performance with respect to the site conditions and contaminant characteristics. Remedial action technologies and their corresponding process options that are considered applicable based primarily on technical implementability are given a "yes" rating. Technologies or process options that are given a "no" rating are screened out and are not carried forward for further analysis.

The technology process options retained after the initial screening are then thoroughly evaluated based on overall effectiveness, implementability, and cost. The remedial technologies/process options retained for further analysis are combined to provide remedial alternatives to protect human health and the environment. The following remedial technologies were selected to prevent exposure to contaminated groundwater by managing the contaminant migration:

- No remedial action (long-term monitoring)
- No remedial action (groundwater-use restrictions)
- Groundwater extraction and pumping
- Onsite treatment by:
  - Carbon adsorption

- Air stripping
- Multi-media filtration
- Precipitation/flocculation
- In-situ microbial degradation
- Offsite treatment at an industrial water treatment plant (IWTP)
- Infiltration Gallery
- Direct discharge to Willoughby Bay
- Air sparging/soil vapor extraction (AS/SVE)

## Development and Detailed Analysis of Alternatives

By combining the selected technologies listed above, five alternatives were developed for this FS to address the remedial action objectives and meet the federal guidance categories. Each of the five remedial alternatives is evaluated in detail, including a detailed description identifying all the components necessary for evaluation and a detailed analysis considering the following nine evaluation criteria:

- Short-term effectiveness
- Long-term effectiveness
- Reduction of mobility, toxicity, or volume
- Implementability
- Cost
- Compliance with ARARs
- Overall protection of human health and the environment
- State acceptance
- Community acceptance

The last two criteria will be evaluated following review and comment on the RI/FS report and will be addressed once a final decision is made and the Record of Decision (ROD) is prepared.

## Individual Analyses of Groundwater Alternatives

### Alternative 1: No-Action, Institutional Controls

This no remedial action alternative consists of no treatment, containment, or removal of the contaminated media; implementing monitoring to determine access and exposure to contaminated groundwater; and continued water-use restrictions. The alternative involves installing groundwater monitor wells, analyzing groundwater samples, and additional contaminant transport modeling.

### Alternative 2: Groundwater Collection, Treatment, and Onsite Discharge

Alternative 2 involves installing groundwater monitor wells, constructing a water treatment system, and discharging treated water to the Elizabeth River. The treatment system includes

air stripping to remove VOCs. Discharge to the Elizabeth River will be via existing storm sewer lines.

#### Alternative 3: Groundwater Collection, Pretreatment, and Offsite Treatment and Discharge

This alternative includes installing groundwater monitor wells, pretreatment by air stripping to remove VOCs, and discharge to the Naval Base Industrial Waste Treatment Plant (IWTP).

#### Alternative 4: Collection, Onsite Treatment, Onsite Discharge, and In-Situ Treatment

Alternative 4 requires installing groundwater monitor wells, installing a water treatment system (air stripping), installing biologic nutrient and catalyst control units, followed by infiltration gallery into the aquifer to stimulate in-situ microbial degradation.

#### Alternative 5: Air Sparging/Soil Vapor Extraction

This alternative includes installing AS wells in conjunction with SVE wells to remove VOCs from both groundwater and adjacent soils.

### **Comparative Analysis of Alternatives**

The five alternatives are compared with respect to the seven evaluation criteria. Final alternative selection for the ROD is based on this comparative analysis.

#### Short-Term Effectiveness

Groundwater Alternatives 2, 3, 4, and 5 are more effective in reducing aquifer contamination than the no remedial action alternative. Alternative 4 will meet the remedial response objectives in a shorter time period than alternatives 2 and 3.

#### Long-Term Effectiveness

All groundwater and soil remedial alternatives, except the no-action alternatives and the source containment alternative, remove contaminants from the site and do not leave any untreated waste or residuals that require managing to ensure an adequate level of protection. Groundwater Alternatives 4 and 5 provide the greatest degree of protection because microbial degradation will speed up groundwater restoration and ensure complete remediation.

#### Reduction of Mobility, Toxicity, or Volume

Groundwater Alternative 4 will provide the greatest degree of contaminant destruction and therefore the greatest degree of mobility, toxicity, and volume reduction. Alternatives 2, 3, and 5 will also provide a similar reduction; however, Alternative 5 provides a quick reduction due to the additional in-situ treatment of VOCs.

### Implementability

All of the remediation alternatives for groundwater and soil are technically feasible. Each alternative can be constructed and operated on reliable technologies that are both effective and proven. However, for Alternatives 4 and 5, the actual degradation rate and system parameters are unknown until a biologic treatability study is performed. The no-action alternative for groundwater is easy to implement. Implementation of the remediation alternatives from an administrative standpoint is not estimated to be a major concern because the QADSY is on Navy property. Permits would be required for any air emissions from stripping towers and low-temperature rotary dryers; a NPDES permit would be required for surface water discharge from the groundwater treatment systems. The operational permit process for the infiltration gallery is not well defined.

### Cost

Alternative 5 has the highest capital cost and alternative 3 has the highest present worth of the groundwater scenarios. Alternative 1 is more sensitive to the discount rate than the other groundwater alternatives.

The alternatives' present worth costs change by approximately 33 to 43 percent when cleanup is cut in half, and by approximately 61 to 80 percent when doubled. Groundwater Alternatives 2 and 3 have similar sensitivity to a change in the groundwater flow rate. Reducing the flow rate by half reduces the present worth value by approximately 29 to 44 percent. Doubling the flow rate similarly increases the present worth cost by approximately 57 to 87 percent.

Alternatives 2 and 3 demonstrate the greatest sensitivity to the replacement cost because capital expenditures are a greater portion of the alternatives' present worth cost.

### Compliance with ARARs

Groundwater Alternatives 2, 3, 4, and 5 will all meet chemical-specific ARARs following completion of the treatment phase. Action-specific ARARs will also be met by Alternatives 2, 3, 4, and 5.

### Overall Protection of Human Health and the Environment

Groundwater Alternatives 2, 3, 4, and 5 will provide adequate protection to human health and the environment following treatment of the contaminated groundwater.

Alternative 1 will provide protection to human health, but will not be protective of the environment.

## 10.0 INTRODUCTION

### 10.1 Purpose

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 requires each federal facility listed on the Federal Agency Hazardous Work Compliance Docket to follow the rules, regulations, guidelines, and criteria established by the United States Environmental Protection Agency (EPA) for the Superfund Program. Subpart E of the National Oil and Hazardous Substances Contingency Plan (NCP of March 1990) establishes methods and criteria for determining the appropriate extent of response and outlines procedures for determining the nature and extent of contamination at a site. These methods and criteria are more commonly referred to as the Remedial Investigation/Feasibility Study (RI/FS).

The United States Navy retained Environmental Science and Engineering, Inc. (ESE) to conduct an RI/FS at the Q Area Drum Storage Yard (QADSY) under contract #N62470-90-D-7661, "Indefinite Quantity Contract for Preliminary Assessments (PA), Site Investigations (SI), and Feasibility Studies (FS), and Related Design and Engineering Services at Various Activities under the Cognizance for the Atlantic Division, Naval Facilities Engineering Command." This FS report summarizes the process used to develop and evaluate remedial action alternatives addressing current or future potential risks to the public health or the environment. In accordance with the NCP, "The purpose of the remedy selection process is to implement remedies that eliminate, reduce, or control risks to human health and the environment" (CFR 300,430,(a),[1]).

This FS report is based on the information presented in Volume I of this document, the Remedial Investigation Report for the QADSY, Norfolk Naval Base, Norfolk, Virginia. The methodology in this FS report allows a step-by-step evaluation of technologies, alternatives, and assembled alternatives by progressing through a series of screenings (Figure 10-1). Initially, general qualitative information is used. Subsequently, more refined and quantitative information is used to eliminate unfeasible or otherwise unacceptable actions from consideration. This methodology provides a systematic procedure for identifying and evaluating alternatives, specifying criteria for determining the magnitude and importance of effects resulting from the implementation of an action, and considering measures to mitigate adverse effects.

### 10.2 Organization Of This Report

This FS Report begins with the introduction, Section 10.0, which describes the purpose of the report and the site background, including a brief summary of the findings of the RI. Section 11.0 identifies remedial action objectives, general remedial response action, applicable or relevant and appropriate requirements (ARARs), the volume or area of contaminated media,

and remedial technologies and process options. Further, technologies are identified and screened.

Section 12.0 develops alternatives by assembling selected technologies into alternatives covering each media. The assembled alternatives are then developed to a level of detail that enables thorough analysis and cost estimation accurate to within a range of +50 percent to -30 percent. In Section 12.0, the alternatives are analyzed in relation to nine criteria developed by EPA. A comparative analysis of the individual alternatives is also described. Tables and figures are presented at the end of each section.

### **10.3 Site Description**

The QADSY was created by a fill operation in the early 1950s and was used as a disposal area for dredged materials excavated from Willoughby Bay. The site is a relatively flat, open earthen yard covered by crush-and-run gravel; it is bounded on the north and west by asphalt-paved parking lots.

### **10.4 Site History**

The QADSY has been in use since its creation in the 1950s, and tens of thousands of drums have been stored at the site since that time (LANTNAVFACENGCOM, 1988). A variety of materials were stored in 55-gallon steel drums, including petroleum products (such as oil lubricants), various organic solvents, paint thinners, some pesticides, formaldehyde, and acids. Throughout the site's history, the northern portion of the yard was used to store damaged and leaking drums.

During a site visit in June 1990, drum storage occurred in three general areas:

- Hazardous Materials (HM) Area
- Petroleum Products Area (PPA)
- Transit Area (TA)

These areas are described in detail in Section 3.2 of the RI report. Various products were stored onsite at the time of the site visit, including chlorinated solvents, hydraulic fluid, and lube oil.

Sometime between the June 1990 site visit and the initiation of the field investigation in September 1990, the majority of the drums were moved to the CD Drum Storage area. The drums are currently stored in sheds with secondary containment and drains to a fuel oil recovery system.

### **10.5 Results Of The Remedial Investigation**

The objective of the RI was to determine the nature and extent of contamination at the site, as well as locate and characterize the groundwater contamination both onsite and offsite. The

complete results of the RI are presented in Volume I of this document, the RI report for the QADSY.

During the RI, six study areas were designated at the site based on past activities. The study areas included: the HM Area, PPA, TA, Truck and Equipment Storage Yard (EY), and Fleet Parking (FP, west of the QADSY).

The RI field investigation was performed in two stages: (1) a 1990 groundwater and soil sampling event; and (2) 1992-1993 groundwater, 1992 soil, 1992 surface water, 1993 sediment, and 1995 soil and groundwater sampling events.

To fulfill the objectives of the RI, ESE performed the following tasks:

- A total of 18 monitor wells were installed. Ten of the wells comprise four well clusters. Each cluster consists of two or three wells that monitor the shallow and deep portions of the aquifer beneath the site. Subsurface soil samples were collected from wells SW-1 through SW-5.
- Surface soil samples were collected from 36 locations from the four study areas during the 1990 sampling event. Samples were collected from two intervals in 24 of the borings: 0 to 18 inches and 18 to 36 inches. A composite sample was taken from 0 to 36 inches in the remaining 12 borings.
- Subsurface samples were collected from eight locations during the 1992 sampling event to further delineate the extent of total petroleum hydrocarbon (TPH) contamination. Samples were collected from two intervals in the borings: 3 to 5 feet and 5 to 7 feet.
- During the May 1995 sampling event, surface soil samples were collected at 19 locations. Fifteen of these were analyzed to further delineate the extent of TPH contamination. The remaining four were analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), inorganic compounds (IOCs), and cyanide.
- Two sediment samples were collected from onsite storm drains.
- During the 1990 sampling event, groundwater samples were collected from the ten new wells and from three existing wells installed as part of the Initial Assessment Study (IAS). During the 1992-1993 sampling event, groundwater was collected from five of the wells installed in 1990 and from the eight new wells installed in 1992. Groundwater samples were collected from the eight new wells in May 1995.
- 66 groundwater samples from 18 locations were collected using the hydropunch sampling technique in December 1992. The samples were analyzed for Trichloroethene (TCE), Tetrachloroethene (PCE), and 1,2-Dichloroethane (DCA)



using a Photovac field gas chromatograph. At least two hydropunch samples were collected at each location. Groundwater samples were collected at 10-foot intervals beginning at 15 feet below surface. Hydropunch samples were collected until the contamination was below detection limits or two consecutive samples were detected at or below 5 micrograms per liter ( $\mu\text{g/l}$ ).

- One surface water sample was collected from the Elizabeth River adjacent to the piers.
- Rising and falling head slug tests were used to determine the hydraulic conductivity of the aquifer. Continuous water level monitoring was conducted on one shallow and one deep well to determine tidal and recharge influences on the aquifer.
- The vertical flow regime between the aquifer and the Elizabeth River was determined by installing a piezometer at the end of one of the piers.
- A 72-hour drawdown test was performed to evaluate aquifer characteristics including specific capacity, transmissivity, storativity, and area of influence.
- Following the 1992 field investigation, MODFLOW®, a three-dimensional groundwater flow model, was used to determine groundwater flow lines at the site.
- Monitor well locations were surveyed to determine the elevation of each well; additional surveys were performed to develop accurate site maps.
- Two air sparging/soil vapor extraction (AS/SVE) pilot studies were performed in May 1995 to test the feasibility of a remediation system.

General conclusions were made based on the data obtained from the RI, as described in the following sections.

### 10.5.1 Hydrogeology

The hydrogeologic investigation at the QADSY was conducted in three phases: installing and sampling new monitor wells and soil borings between August and October 1990; existing monitor well sampling and the pump test were performed between January and February 1991; rising and falling head slug tests were performed during March 1991; five of the monitor wells installed in 1990 were sampled in October 1992; eight new wells were installed and sampled in January 1993; and continuous water level monitoring of tidal effect was performed in December 1992 and January 1993 for 34 days. The following general conclusions were made:

- A single, unconfined aquifer has been identified at the site, ranging from approximately 7 feet below ground surface to at least 75 feet.

- The aquifer consists of sands and silty sands (and fill material).
- Groundwater flow in the aquifer is generally to the west across the site.
- Groundwater average linear velocity in the aquifer averages 15 feet per year, but may vary greatly due to local changes in hydraulic gradient and hydraulic conductivity.
- Static water levels at the site are influenced up to 3 feet within the QADSY by the tides.
- The AS/SVE pilot studies indicated that AS/SVE is a feasible remediation technique at the QADSY.
- The aquifer is contaminated with VOCs.

A generalized geologic section of the site is provided in Figure 3-3 of the RI report.

### **10.5.2 Nature and Extent of Contamination**

A variety of contaminants have been identified at the site. A list (Table 10-1) of compounds of concern (target compounds) was created from the contaminants identified.

The following factors were considered when identifying the target compounds:

- Relation to known or suspected site activity
- Frequency of detection above background levels and/or relevant standards/criteria
- Frequency of detection above those mandated by NEESA Level C Protocols
- Compound presence in laboratory or field blanks

Several compounds identified at the site are recognized laboratory contaminants. These compounds are not the focus of the FS and therefore are not relevant. In addition, the treatment proposed for PCE and TCE will also eliminate these compounds if they are present at low levels.

A brief summary follows of the sample results from each media investigated during the RI. Figures 2-1 and 2-2 of the RI report show the locations sampled during the investigation. Media included groundwater, surface soils, subsurface soils, sediment, and surface water. Figures 5-6 through 5-38 of the RI report show the location of the monitor wells and interpreted contaminant plumes. Additional details regarding the site can be found in Sections 3.0 through 8.0 of the RI Report.

#### **Surface Soils:**

- Fifty percent of the 0- to 3-foot samples from the TA, PPA, and HM areas were contaminated by petroleum hydrocarbons above the 100 parts per million (ppm)

Commonwealth of Virginia Department of Environmental Quality (VDEQ) action level. Two-thirds of the samples exceeded the 50 ppm VDEQ guideline for disposal of the soil as clean fill. Concentrations ranged from not detected to 4400 ppm. A hydrocarbon that closely matched the reference standard for compressor oil was the most common; other oils were less common. All of the 3- to 7-foot samples were below the 50 ppm VDEQ guideline.

- Soil VOC contamination is limited. Only the sample from location HM-9-2, at 32,000 micrograms per kilogram ( $\mu\text{g/kg}$ ) PCE, exceeded the range for all other samples of 1000  $\mu\text{g/kg}$  total VOCs. Other VOCs detected at much lower levels included: acetone, xylenes, 1,1-DCA, toluene, methylene chloride, 1,2-Dichloroethene (DCE), 1,1,1-Trichloroethane (TCA), TCE, 4-methyl-2-pentanone, and 1,1,2,2-Tetrachloroethane (PCA).
- All detected toxic characteristic leachate procedure (TCLP) organics and IOCs were well below federal standards.
- The highest VOC and TPH concentrations occurred within the HM and PPA areas.
- Many of the compounds detected in the surface soils were also detected in the groundwater samples, including VOCs, TPH, and IOCs.

#### Groundwater:

- The contaminants present in the saturated zone were comparable to those observed in the soils and are typical of the type of contaminants stored at the site except for TPH.
- Contamination appears to affect the upper 60 feet of the aquifer.
- The main groundwater contaminants of concern are the following chlorinated organics: PCE, TCE, 1,1,1-TCA, 1,1-DCA, 1,1-DCE, 1,2-DCE, and acetone. Locally, some IOC concentrations were elevated (e.g., cadmium).
- As determined in the hydrogeological investigation, groundwater flows west across the site. A contaminant plume has developed downgradient from the HM Area. A second plume (probably not directly associated with the QADSY) has developed along the bulkhead between Piers 11 and 12.

### 10.5.3 Contaminant Fate and Migration

Contaminant fate and transport at the QADSY was based on the characteristics of the compounds of concern and their relationship with the geologic and hydrogeologic conditions that exist there.

- No free-phase product was found at the site.
- VOCs have migrated downward through the vadose zone, encountering the saturated zone. They were then transported with the groundwater flow in a westerly direction.
- VOC concentrations in the site soils are not likely to act as continuing sources of groundwater contamination.
- Groundwater movement and contaminant behavior indicate that advection (the process by which contaminants are transported by the bulk motion of flowing groundwater) is the primary transport mechanism for VOCs in the aquifer.

#### 10.5.4 Risk Assessment

An RA was generated in accordance with EPA region-wide and Region III guidance to assess the potential current and future human and ecological health risks associated with potential onsite exposures at the QADSY, assuming no remedial action is implemented at the site. The risk results are then used to develop remedial goal objectives (RGOs), goals which remedial alternatives strive to achieve considering other factors such as feasibility and achievability.

The RA identified the primary site-related chemicals of potential concern (COPCs) at the QADSY. Based on past site operations and disposal activities at the site, the COPCs evaluated in the Human RA (HRA) and Ecological RA (ERA) include a subset of VOCs and IOC. The data used in the RA is taken from ESE sampling events (1990-1993) and sampling events from different contractors (Malcolm Pirnie, 1983-1986 and Baker Environmental, 1995). The most recent and/or reliable data are used in the calculation of the exposure concentrations for the RA. The number of chemicals to be evaluated in the RAs was reduced using 1) EPA Region III methodology for risk-based concentration screening, 2) comparison of site and background soil concentrations, and 3) a screening for nutritionally essential chemicals.

In addition, TPH was detected at the site. Although this group of chemicals is useful for determining the extent of petroleum-based contamination, a quantitative risk evaluation is not performed as TPH represents a large group of chemicals, typically composed of long, straight-chain hydrocarbons of relatively low toxicity. However, to provide a conservative risk evaluation, the carcinogenic polynuclear aromatic hydrocarbons (PAHs) were used as a surrogate to evaluate TPH.

The exposure assessment identified significant human and ecological exposure pathways and population(s) based on the environmental fate/transport analysis; determines the exposure concentrations to potential receptors; and estimates the magnitude, duration, and frequency of exposure for each receptor (or receptor group). The primary exposure pathways evaluated in the HRA and ERA are as follows:

### Human Exposure Pathways

Current Worker -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

Future Worker -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

Future Residential -- incidental ingestion and direct contact with site soils; inhalation of vapors volatilized from groundwater into indoor air.

### Ecological Exposure Pathways

Terrestrial -- ingestion of contaminated fish by great blue heron.

Aquatic -- exposure to surrounding surface water and sediment by aquatic and benthic organisms.

Domestic groundwater consumption is an incomplete human exposure pathway as the water below the QADSY site is not potable due to the high salinity of the water. Thus, this pathway, under the guidance of State and Federal regulatory agencies, is not further evaluated in the RA. However, due to the presence of VOCs in groundwater beneath the site, inhalation of VOCs volatilized from groundwater into indoor air is evaluated.

The primary sources of toxicological data were from EPA-verified references. When an appropriate toxicological constant was not identified, current literature was reviewed to find appropriate toxicological data, which were used to calculate dose-response values using the methodologies outlined in EPA guidance documents.

The site-specific human carcinogenic and noncarcinogenic risk estimates are determined using the exposure concentrations and factors presented in the exposure assessment along with the dose-response information developed in the toxicity assessment. The potential carcinogenic risks are compared with the EPA target cumulative risk range of  $1 \times 10^{-6}$  (1 in 1,000,000) to  $1 \times 10^{-4}$  (1 in 10,000) [NCP, 40 Code of Federal Regulations (CFR) 300, 430:62].

When a cumulative carcinogenic risk (risk associated with exposure to a mixture of chemicals) to an individual receptor under the assumed exposure conditions at a Superfund site exceeds  $10^{-4}$ , CERCLA generally requires remedial action at the site (EPA, 1991d). If the cumulative risk is less than  $10^{-4}$ , action generally is not required but may be warranted if a chemical-specific standard that is risk based [e.g., the maximum contaminant level (MCL) or an ambient water quality criterion (AWQC)] is violated. A risk-based remedial decision could be superseded by the presence of noncarcinogenic impact or environmental impact at the site as indicated by a hazard index (HI) greater than 1 for human noncarcinogenic exposures or an exceedance of an ecotoxicity quotient (EQ) of 1 for aquatic or terrestrial exposures.

### **Human Risk Characterization Results**

The results of the HRA indicate that the following scenarios exceed either a cumulative risk of  $10^{-4}$  or an HI of 1:

Exposure Scenario	Medium	Exceedance	COCs
Future Worker	Indoor air	Risk > $1 \times 10^{-4}$	carbon tetrachloride, chloroform, 1,1-dichloroethene, tetrachloroethene, trichloroethene, and vinyl chloride
		HI > 1	carbon tetrachloride
Future Residential (Lifetime)  (Child)	Indoor air	Risk > $1 \times 10^{-4}$	carbon tetrachloride, chloroform, 1,1-dichloroethane, 1,1-dichloroethene, tetrachloroethene, 1,1,1-trichloroethane, trichloroethene, vinyl chloride
	Indoor air	HI > 1	carbon tetrachloride, 1,1-dichloroethane, 1,1,1-trichloroethane
	Soil	HI > 1	thallium

### Ecological Risk Characterization Results

Terrestrial--The EQs associated with exposure of great blue heron to site contaminants due to ingestion of fish are all less than 1, suggesting that there is low potential for adverse effects to the great blue heron due to site-related chemicals in fish caught near the site.

Aquatic--The EQs for water- and sediment-dwelling aquatic organisms at QADSY are all less than 1, indicating that there is low potential for adverse effects to these aquatic organisms.

### Remedial Goal Objectives

The Superfund Amendments and Reauthorization Act of 1986 (SARA) requires that remedial actions attain a degree of contaminant cleanup that ensures protection of public health and the environment. Thus, the risk characterization results are used to identify whether site COPCs need to be reduced to acceptable health-based levels. The acceptable health-based levels are referred to as RGOs, which are chemical-specific concentration goals for individual chemicals for specific medium and reasonable land use combinations.

Based on the results of the risk characterization, future worker exposure to indoor air and future residential exposure to indoor air and soil resulted in a cumulative risk exceeding  $10^{-4}$  and/or an HI exceeding 1. However, to provide a complete site analysis, RGOs are developed

for all chemicals contributing an individual risk of at least  $10^{-6}$  to a total of greater than  $10^{-4}$  or on HI of at least 0.1 to a total HI of greater than 1. Ecological risk characterization results indicated that several IOCs in soil produced an excess EQ in mice and raccoon; therefore, RGOs were developed for these IOCs in soil based on these two receptors. In summary, RGOs are developed for the following chemicals to provide risk managers with the maximum risk-related media level options on which to develop remediation aspects of the FS:

Medium	Scenario	COCs	RGO
Groundwater	Future Worker	Carbon tetrachloride	2.7 µg/l
		chloroform	11.1 µg/l
		1,1-dichloroethene	0.38 µg/l
		tetrachloroethene	59.6 µg/l
		trichloroethene	48.9 µg/l
		vinyl chloride	0.08 µg/l
	Future Resident	Carbon tetrachloride	1.8 µg/l
		chloroform	7.4 µg/l
		1,1-dichloroethane	540 µg/l
		1,1-dichloroethene	0.26 µg/l
		tetrachloroethene	38.9 µg/l
		1,1,1-trichloroethane	3790 µg/l
		trichloroethene	32.6 µg/l
		vinyl chloride	0.05 µg/l
Soil	Future Resident	Thallium	12.5 mg/kg

The QADSY is located in a highly industrial area at the Norfolk Naval Base in Norfolk, Virginia. The present future plan at the QADSY is to increase the fleet ship parking by paving the current five acre gravel area. There are no future building plans although the recommended remedial action objectives are for the future worker. The future resident scenario is highly unlikely because of the location of the QADSY.

**INTRODUCTION  
(Section 10.0)**

- Review of RI Results

**IDENTIFICATION AND PRELIMINARY SCREENING  
OF REMEDIAL TECHNOLOGIES  
(Section 11.0)**

- Identify remedial action objectives
- Identify volumes/areas of groundwater and soil contamination
- Identification and screening of applicable remedial technologies based on site conditions and contaminant characteristics

**DEVELOPMENT AND DETAILED ANALYSIS OF ALTERNATIVES  
(Section 12.0)**

- Develop alternatives
- Assemble alternatives
- Analyze alternatives based on:
  - Protection of health and environment
  - ARARs
  - Reduction of toxicity, mobility, volume
  - Long-term effectiveness
  - Short-term effectiveness
  - Implementability
  - Cost
- Compare alternatives

**Figure 10-1. Feasibility Study Process  
Q Area Drum Storage Yard  
Norfolk Naval Base**



**Table 10-1. Q Area Drum Storage Yard Target Compounds**

- Tetrachloroethene (PCE)\*
- Trichloroethene (TCE)\*
- 1,1-Dichloroethene (DCE)\*
- Vinyl chloride\*
- Carbon tetrachloride\*
- Chloroform\*
- Barium\*\*
- Iron\*\*
- Lead\*\*
- Manganese\*\*
- Thallium\*\*
- Vanadium\*\*

\* Indicates compound detected in groundwater above RGO concentration

\*\* Indicates compound detected in surface soil above RGO concentration

## 11.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

Remedial technologies are identified and screened in this section. This process includes three tasks:

- Develop remedial action objectives based on site characteristics, specifying the contaminants and media of interest.
- Identify general response actions for each medium of interest, defining remedial actions singly, or in combination, that may satisfy the remedial objectives and potential ARARs for the QADSY.
- Identify and screen technology types and process options applicable to each general response action.

The initial task is to identify site problems in terms of contaminated media. A description of the contaminated media is provided in Section 10.0 and includes information and data pertaining to the sampling program, physical characteristics of contaminated media, results of the analytical testing, and extent of contamination. Remedial action objectives, general remedial response actions, and potential ARARs are identified to address the site problem (i.e., contaminated media). Specific remedial action technology types are identified for each of the general response actions. These technology types may be further broken down into specific process options.

After the remedial technologies and process options are identified, the technologies are subjected to a preliminary screening to determine their applicability. This screening is based on specific site criteria including site conditions, contaminant characteristics, and potential ARARs. Technologies and process options that pass the preliminary screening are evaluated based on implementability, effectiveness, and cost. It is possible that any process options that pass the initial screening could be selected for implementation during remedial design. By selecting one process option to represent a technology type, the alternative assembly process becomes more streamlined and manageable.

Many technologies ineffective by themselves are retained to be combined with other technologies to form alternatives specifically applicable to the QADSY site. To remain consistent with data provided in the RI Report for the QADSY, the same study areas and their designations used in the RI report will be used throughout the FS Report.

### 11.1 Remedial Action Objectives and Goals

The NCP states, "The appropriate extent of remedy shall be determined by the lead agency's selection of a cost-effective remedial alternative that effectively mitigates and minimizes threats to and provides adequate protection of public health and welfare and the environment"

(40 CFR 300.68(i)). This is the general goal of all CERCLA FSs. Based on the results of the RI, the following contaminated media are considered for potential remediation:

- Groundwater
- Surface Soils

To satisfy the general objective of the NCP, specific remedial action objectives for the contaminated media follow. Numerical remedial action goals are presented in Table 11-1.

### **11.1.1 Groundwater**

The remedial action objectives for groundwater are: (1) the adequate protection of human health from inhalation of VOCs in the groundwater extracted from the aquifer; and (2) the adequate protection of human health and the environment from the discharge of groundwater to surface water.

### **11.1.2 Surface Soils**

A remedial action objective for surface soils at the site is to prevent ecological exposure to contaminated soil through ingestion.

## **11.2 ARARs**

CERCLA Section 121 requires that remedial actions comply with the requirements of all federal and state environmental regulations (ARARs).

Applicable requirements mean those cleanup standards, standards of control, and other substantive environmental protection standards, requirements, criteria, or limitations promulgated under federal and state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site. Applicable requirements are specific to the conditions present on the site for which all of the jurisdictional prerequisites of the law are satisfied.

Relevant and appropriate requirements are those standards promulgated under federal and state law, that while not "applicable," address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. A requirement that is judged to be relevant and appropriate receives the same degree of compliance as if it were applicable.

To-be-considered (TBC) criteria are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of ARARs. However, in many circumstances TBCs will be considered in addition to ARARs as part of the site risk assessment and may be used as the level of cleanup for protection of human health or the environment.

ARARs apply to actions or conditions located onsite and offsite. Onsite actions implemented under CERCLA are exempt from having to meet administrative requirements of federal and state regulations such as permits, as long as the substantive requirements of the ARARs are met. Offsite actions are subject to the full requirements of the applicable standards or regulations, including all administrative and procedural requirements.

Based on the CERCLA statutory requirements, the remedial alternatives developed in this FS will be analyzed for compliance with federal and state ARARs. This process involves initially identifying potential requirements, evaluating the potential requirements for applicability or relevance and appropriateness, and determining the ability of the remedial alternatives to achieve the ARARs.

For discussion purposes ARARs can be divided into three groups: chemical-specific, location-specific, and action-specific.

- Chemical-specific ARARs include those laws and regulations governing the release of materials possessing certain chemical or physical characteristics, or containing specified chemical compounds. These requirements generally set health or risk-based concentration limits or discharge limitations in various environmental media for specific hazardous substances. Examples include drinking water standards and ambient air quality standards.
- Location-specific ARARs are design requirements or activity restrictions based on the geographical or physical position of the site and its surrounding area. Examples include areas in a flood plain, a wetland, or an historic site.
- Action-specific ARARs are technology-based and establish performance, design, or other similar action-specific controls or regulations on activities related to the management of hazardous substances or pollutants. An example includes RCRA incineration regulations. Action-specific ARARs are evaluated in Section 12.0 after specific remedial alternatives are identified.

Potential chemical-, location- and action-specific ARARs are listed in Appendix O.

### **11.3 General Response Actions**

General response actions are medium-specific groups of remedies which are assembled to meet the remedial action objectives at the site. General response actions have been identified for soil and groundwater. Although separated to address specific remedial action objectives, the majority will work in conjunction with other general response actions to meet all remedial action objectives. The general response actions identified for each contaminated media, with corresponding remedial action category, are presented in Table 11-2.

Available remedial action technologies and process options associated with each general response action are presented in Table 11-3. For instance, capping and vertical barriers are

two remedial action technologies for the containment general response action. In addition, there may be several capping options such as multi-media RCRA, synthetic membrane, etc.

In developing alternatives in Section 12.0, combinations of general response actions are identified, and based on the RI, an initial determination is made of areas or volumes of contaminated groundwater to which these general response action combinations might be applied (Appendix P). The approximate extent of groundwater contamination was mapped based on the most recent groundwater sampling conducted during the RI along with hydrogeologic conditions at the QADSY. Contaminated groundwater volumes were calculated using the interpreted plume area shown in Figure 11-1.

The QADSY was created by a fill operation as a disposal area for dredged materials excavated from the James River, Elizabeth River, and/or Willoughby Bay in the early 1950's. The dredged material has been recognized to contain elevated levels of IOCs contamination. There are no records where the dredged material came from or may be from numerous sources.

Background soil data was collected at a upgradient located adjacent to Bousch Creek. Background soil data indicated IOC data was within a order of magnitude from the highest concentration measured during the RI. The IOC impacted soil will be too complex to delineate because of the unknown source or sources of the dredged material. The IOC contamination appears to be inherited in the dredged material and not from the drum storage yard because of the measured IOCs levels are similar to background.

The RGOs for soil are from IOC contamination for ecological concerns. The recommended remedial action for soil is no action because the future plans are for the QADSY to be paved, and subsequently terminating this ecologic risk pathway.

## **11.4 Identifying and Screening Technology Types and Process Options**

At this stage in the FS development, a preliminary identification and screening of the complete array of remedial technology types and technology process options takes place. The purpose is to produce a condensed list of applicable remedial action technologies along with their corresponding process options that may be assembled into suitable alternatives to control the contaminated media at the QADSY.

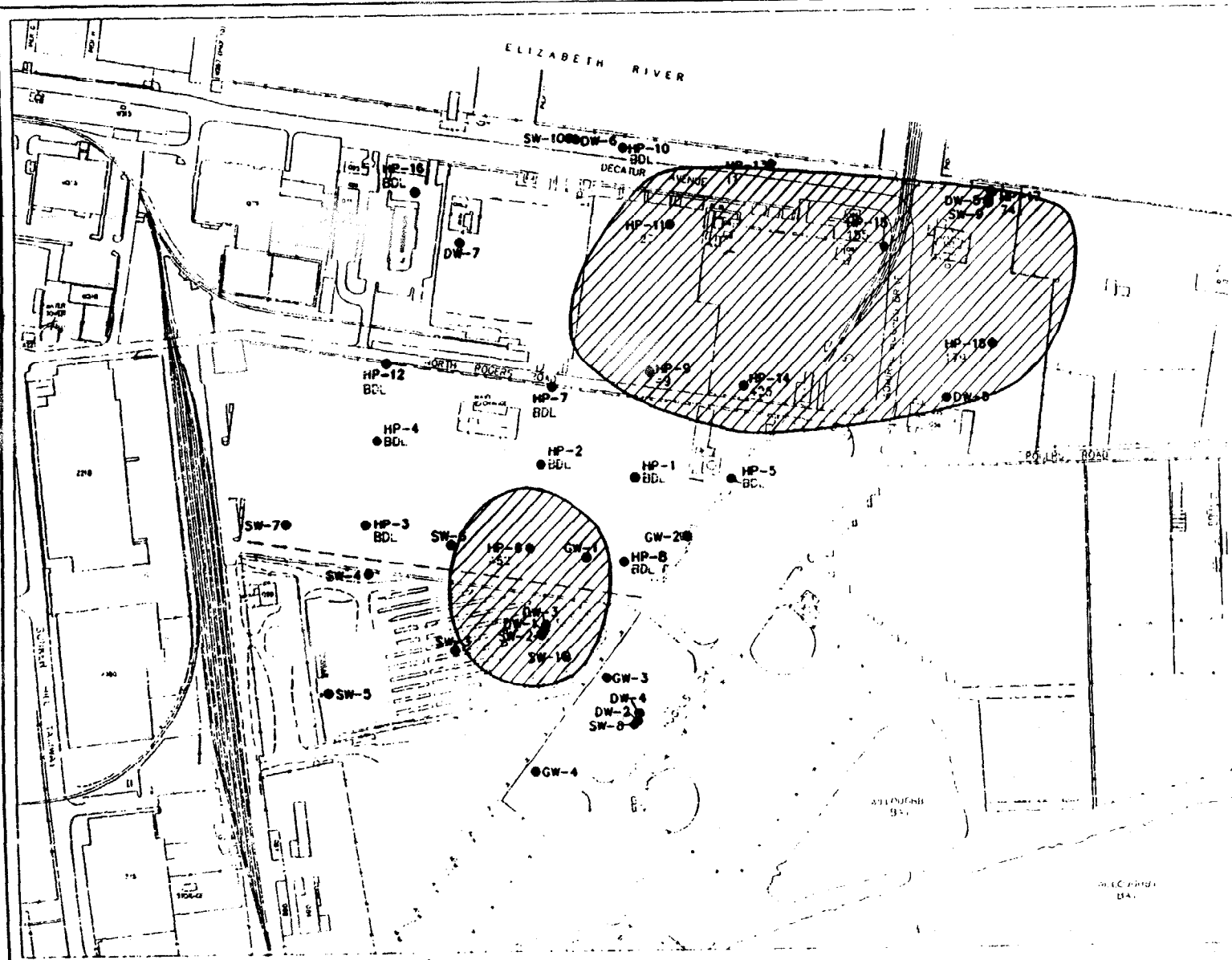
### **11.4.1 Identifying and Screening Technologies**

Applicability of each technology was evaluated by reviewing its potential performance with respect to the site conditions and contaminant characteristics discussed in Section 10.0. Screening the remedial action technologies and their corresponding process options are detailed and presented in Table 11-4. Those that are considered applicable based primarily on technical implementability are given a "yes" rating. Technologies or process options that are given a "no" rating are screened out and will not be carried forward for further analysis.

Table 11-5 summarizes the technologies that passed this initial screening. Technologies that survived this initial screening but are not carried through the remainder of this FS may still be considered during the Remedial Design.

#### **11.4.2 Evaluating Technology and Selecting a Representative Technology**

The technology process options retained after the initial screening are thoroughly evaluated based on overall effectiveness, implementability, and cost. A summary of the evaluation is presented in Table 11-6. One or more representative technology process options are selected (Table 11-7) as representative to simplify the subsequent development and evaluation of alternatives within the FS. The selection of representative technologies is merely a basis for developing a remedial design concept in this FS: it is not intended to exclude other feasible technologies that may still be selected during the remedial design phase, even though they were not developed in this FS.



# LEGEND

- HYDROPUNCH LOCATION
- MONITOR WELL LOCATION
- VOC CONTOUR LINE
- ▨ VOCs ABOVE RGO



**Environmental  
Science &  
Engineering**

DATE  
11-2-95

DRAWN BY  
TJS

JOB NO.  
4921150

SCALE  
SHOWN

APPROVED BY

DWG. NO./ REV. NO  
QDK / -

TITLE

AREA USED FOR VOC IMPACTED  
GROUNDWATER VOLUME CALCULATIONS  
Q AREA DRUM STORAGE YARD  
NORFOLK NAVAL BASE, NORFOLK, VA.

CLIENT

NAVFAC - Q AREA

FIGURE

11-1

**Table 11-1. Remedial Action Goals**

Indicator chemical	Groundwater RGO (µg/l)	Soil RGO (mg/kg)
Tetrachloroethene (PCE)	59.6	BRGO
1,2-Dichloroethane (DCA)	48.9	BRGO
Vinyl Chloride	0.077	BRGO
1,1-Dichloroethene (DCE)	0.038	BRGO
Carbon Tetrachloride	2.7	BRGO
Chloroform	11.1	BRGO
Barium	BRGO	7.3
Iron	BRGO	3120
Lead	BRGO	13.7
Manganese	BRGO	313
Thallium	BRGO	2.5
Vanadium	BRGO	1.0

RGO = Remedial Goal Objective

BRGO = Below Remedial Goal Objective

**Table 11-2. General Response Actions**

CONTAMINATED MEDIA	GENERAL RESPONSE ACTIONS
Groundwater and Surface Water	No Action Institutional Controls Containment Collection Treatment Discharge In-Situ
Surface Soil, Sediment, and Subsurface Soil	No Action



**Table 11-3. Remedial Technologies**

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	AVAILABLE REMEDIAL TECHNOLOGY AND PROCESS OPTIONS
GROUNDWATER	No Action	None
	Institutional Controls	Groundwater Use/Restrictions Groundwater Monitoring
	Containment	Capping: Synthetic Membrane Clay Asphalt Concrete  Vertical Barriers: Slurry Walls Vibrating Beam Grout Curtains Sheet Metal Piling High Density Polyethylene (HDPE)
	Collection	Extraction Wells Subsurface Drains/Trenches
	Treatment: Onsite	Biological: Activated Sludge Trickling Filter Rotating Biological Contactors (RBC) Aerated Lagoon Biophysical Submerged Fixed Film  Chemical/Physical: Neutralization Dechlorination Oxidation/Reduction Precipitation/Flocculation Carbon Adsorption Ion Exchange Reverse Osmosis Filtration Air Stripping Dissolved Air Flotation Liquid/Liquid Extraction Ozone/UV Spray Evaporation

Table 11-3. Continued

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	AVAILABLE REMEDIAL TECHNOLOGY AND PROCESS OPTIONS
GROUNDWATER	Treatment (cont'd): In-situ	Microbial Degradation Activated Carbon Bed Limestone Treatment Bed Chemical Treatment Air Sparging/Soil Vapor Extraction Wastewater Treatment Plant (WTP)
	Offsite	
	Discharge: Onsite	Deep Well Injection Aquifer ReInjection Infiltration Gallery
	Offsite	Direct Discharge to Willoughby Bay

Table 11-4. Screening Available Remedial Technologies

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY-PROCESS OPTION	FURTHER ANALYSIS	COMMENTS
Groundwater	No Action	None	Yes	The NCP requires NO ACTION to be carried through to detailed analysis of alternative.
	Institutional Controls	Groundwater Use/Deed Restrictions	Yes	Restriction on the use of the site and nearby property could be effective in preventing installation of wells within the site and excavation of contaminated soil.
		Groundwater Monitoring	Yes	Monitoring could be effective in tracking contaminants in the groundwater.
	Containment	Capping: - Synthetic Membranes	No	Limited long-term experience. Requires specialized installation. Not suitable for further development at the site.
		- Clay	No	Subject to cracking. RCRA multi-media cap is considered more reliable. Not suitable for further development at the site.
		- Asphalt	No	Subject to cracking. Will contain <u>only</u> soil contaminants. Will allow further use of the site property as parking lot, etc.
		- Concrete	No	Subject to cracking, but if maintained will provide impermeable barrier but <u>only</u> for soil contaminants. Will allow onsite development.
		- Multi-Media RCRA Cap	No	Effective at sealing off source areas. Very complex design. Would not allow redevelopment of site.
		Vertical Barriers: - Slurry Walls	No	Questionable constructability and continuity of installation.



Technology Eliminated from Further Analysis

Table 11-4 (continued)

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY-PROCESS OPTION	FURTHER ANALYSIS	COMMENTS
Groundwater	Containment (cont'd)	- Vibrating Beam	No	Difficult to maintain beam alignments during installation. Difficult to maintain continuity of adjacent segments during installation. Limited field performance data. Area of concern too large.
		- Grout Curtains	No	Long-term continuity is questionable. Not good for medium sands, incapable of attaining truly low permeabilities.
		- Sheet Metal Piling	No	Unpredictable wall integrity. Damage of piles in rocky soils. Requires frequent maintenance to ensure corrosion resistance.
		- High Density Polyethylene (HDPE)	No	Limited field performance data. Compatibility test must be performed. Affected area too large.
	Collection	Extraction Wells	Yes	Effective when aquifers have high intergranular hydraulic conductivity. Widely accepted and proven technology.
		Subsurface Drains/Trenches	No	Aquifer characteristics may limit effectiveness. More effective for soils with lower hydraulic conductivity. Limited to shallow depths (1-20'). Extensive excavation required. Often used in conjunction with barrier walls.



Technology Eliminated from Further Analysis

Table 11-4 (continued)

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY-PROCESS OPTION	FURTHER ANALYSIS	COMMENTS
Groundwater	Treatment: Onsite	Biological - Activated Sludge	No	Requires major design and construction. Difficult to treat influents containing only halogenated compounds (i.e., TCE, DCE).
		- Trickling Filter	No	Used primarily for high BOD wastewaters. Influent not concentrated enough to support microbes. Difficult to treat influents containing only halogenated compounds (i.e., TCE, DCE).
		- Rotating Biological Contactors (RBC)	No	Proven effective in treating TCA and DCA containing waters. Can handle large flow variations and high organic shock loads. Additional treatment may still be required. Difficult to treat TCE and PCE.
		- Aerated Lagoon	No	Difficult to treat low concentrations. Would allow uninhibited volatilization of organic compounds. Not proven in treating chlorinated aliphatic groundwaters.
		- Biophysical	Yes	Provides biological oxidation and carbon adsorption in same unit. Effective on biodegradable and refractory organics. Requires less carbon than carbon adsorption alone. Carbon must be replaced or regenerated.
		- Aboveground Bioreactor	Yes	Can handle high shock loads. Water from bioreactor can be reinjected into aquifer. Not effective for certain contaminants.
		Chemical/Physical: - Neutralization	No	Often used for inorganic acidic/alkaline wastes. Not applicable for QADSY groundwater.
		- Dechlorination	No	Unknown effectiveness on mixed waste in groundwater.
		- Oxidation/Reduction	No	Effective in treating inorganic liquid wastes. Not applicable for QADSY groundwater.

Table 11-4 (continued)

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY-PROCESS OPTION	FURTHER ANALYSIS	COMMENTS
Groundwater	Treatment (cont'd): Onsite	- Precipitation/ Flocculation	No	Applicable for removal of suspended solids, metals, and colloidal particles.
		- Carbon Adsorption	Yes	Removes a variety of organics and some inorganics. Permanent treatment. Modular units available for lease or purchase. A widely used, effective technology. Exhausted carbon must be replaced or regenerated.
		- Ion Exchange	No	Effective in the removal of aqueous metals.
		- Reverse Osmosis	No	Effective in treating high metal wastewaters.
		- Filtration	Yes	Effective for the removal of fine particulate suspended solids including metals adsorbed to solids. Aids in the performance of air strippers and injection wells.
		- Air Stripping	Yes	Removes VOCs from water. Widely demonstrated effectiveness.
		- Dissolved Air Flotation	No	Applicable for removal of oils and greases. Not applicable for QADSY groundwater.
		- Liquid/Liquid Extraction	No	Enables solvent recovery of high concentration liquid wastes. Not applicable to QADSY groundwater.
		- Ozone/UV	Yes	Effective for the removal of chlorinated hydrocarbons in dilute concentration.
		- Spray Evaporation	No	Fails under adverse weather conditions. Contaminated water is jet sprayed into air over large collection ponds. Release of VOCs to atmosphere. Spreading of nonvolatile contamination can occur.



Technology Eliminated from Further Analysis

Table 11-4 (continued)

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	REMEDIAL TECHNOLOGY-PROCESS OPTION	FURTHER ANALYSIS	COMMENTS
Groundwater	Treatment (cont'd): In-situ	Microbial Degradation	Yes	Proven effective in treating aquifers with highly permeable soils and containing TCE, DCE, TCA, DCA, methylene chloride. Complete destruction of waste.
		Activated Carbon Bed	No	Not proven in-situ. Channeling or plugging may occur. Carbon bed must be removed to prevent future release of observed organics.
		Limestone Treatment Bed	No	Primarily used for acidic wastes. Site conditions not suitable for application.
		Chemical Treatment	No	Not effective in treating halogenated compounds. Difficult to ensure proper reactant mixing and verify effectiveness.
		Soil Vapor Extraction	Yes	Proven effective in treating aquifers with highly permeable soils and containing TCE, DCE, TCA, DCA, methylene chloride. Complete destruction of waste.
		Air Sparging	Yes	Proven effective in treating aquifers with highly permeable soils and containing TCE, DCE, TCA, DCA, methylene chloride. Complete destruction of waste.
	Offsite	Wastewater Treatment Plant (WTP)	Yes	Can handle fairly high concentrations of contaminants during normal functioning. Local treatment plant is high capacity.
	Discharge: Onsite	Deep Well Injection	No	Special permits required. Not a readily acceptable method of disposal. Does not reduce contamination.
		Infiltration Gallery (after treatment)	Yes	High treatment standards must be maintained. Infiltration Gallery wells are necessary for implementing in-situ bioremediation.
	Offsite	Direct Discharge to Willoughby Bay	Yes	Requires constant monitoring and a NPDES permit. After groundwater is extracted and treated to meet discharge standards, water can be pumped via pipeline to Willoughby Bay.



Technology Eliminated from Further Analysis

**Table 11-5. Applicable Remedial Technologies Retained for Each Media**

ENVIRONMENTAL MEDIA	REMEDIAL RESPONSE ACTION	REMEDIAL TECHNOLOGY AND PROCESS OPTIONS
Groundwater	No Action	None
	Institutional Controls	Groundwater Use Restrictions Groundwater Monitoring
	Containment	None suitable
	Collection	Extraction Wells
	Treatment: Onsite	Biological: Biophysical Aboveground Bioreactor
		Chemical/Physical: Carbon Adsorption Filtration Air Stripping Ozone/UV
	In-situ	Microbial Degradation Air Sparging/Soil Vapor Extraction
	Offsite	Wastewater Treatment Plant (WTP)
	Discharge	Direct Discharge to Willoughby Bay Infiltration Gallery



**TABLE 11-6**  
**SUMMARY OF DETAILED SCREENING OF**  
**TREATMENT TECHNOLOGIES AND PROCESS OPTIONS**

GROUNDWATER RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
No Action	None	Not Applicable	Does not achieve remedial action objectives.	Not applicable.	None.
Institutional	Groundwater Restrictions	Groundwater Use and Access Restrictions	Effectiveness depends on continued future implementation. Does not reduce contamination.	By being on the Naval Base, is currently subject to restrictions for use.	None.
	Monitoring	Groundwater Monitoring	Useful for documenting conditions. Does not reduce risk by itself.	Readily implementable.	Moderate capital, moderate - high O&M cost.
Collection	Groundwater Collection	Extraction Wells	Effective and reliable; conventional technology.	Readily implementable.	Low capital, and low O&M cost.
Treatment	Chemical/Physical Treatment	Carbon Adsorption	Effective for treatment of a wide variety of organics.	Readily implementable. May require pretreatment.	Moderate capital costs. Potentially high carbon replacement costs.
		Filtration	Effective and reliable as a pretreatment technology.	Readily implementable.	Low capital and O&M cost.
		Air Stripping	Effective for removal of VOCs, exhaust gases may require additional treatment.	Simple, reliable operation. May require subsequent treatment.	Low-moderate capital and O&M cost.
		Precipitation/Flocculation	Effective, will produce sludge that will periodically require disposal.	Simple to implement but requires space to set up.	Moderate capital and O&M cost.
		Ion Exchange	Effective, but is affected by high total dissolved solids and organics concentrations.	Implementable, water would require pretreatment.	Moderate-high capital cost, high O&M cost.
		Reverse Osmosis	Effective, but semi-permeable membranes can clog easily. Only low flow rates can be handled.	Implementable, but could require high maintenance.	Moderate-high capital cost, moderate O&M cost.



Process option eliminated from further analysis.

**TABLE 6 (continued)**  
**SUMMARY OF DETAILED SCREENING OF**  
**TREATMENT TECHNOLOGIES AND PROCESS OPTIONS**

GROUNDWATER RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
Treatment (cont'd)	Chemical/Physical Treatment	UV/Ozone	Limited effectiveness in treating 1, 1, 1-TCA and DCA.	Ultraviolet lamps are susceptible to coating which decreases efficiency.	High capital and O&M cost.
	Biological Treatment	Aboveground Bioreactor	Effective for many organic compounds. Can handle large flow variations and shock loads.	Requires major construction.	Low-moderate capital, low O&M cost.
		Biophysical	Effective option for BOD and organic contamination reduction.	Commercially developed; readily implementable.	High capital, moderate O&M cost.
	In-Situ	Microbial Degradation	If successful can be a very effective option for organic contaminant removal. Uses conventional equipment.	Implementable, but design criteria not fully established. Requires treatability study.	Moderate capital, moderate O&M cost, but usually much shorter period of operation.
	Offsite Treatment	Wastewater Treatment Plant (WTP)	Can handle significant concentrations of organics and metals in water.	Implementable, if WTP can accept discharge.	Moderate capital cost, low O&M cost.
Discharge	Offsite Discharge	Pipeline to Willoughby Bay	Effective and reliable discharge method. Does not eliminate contamination.	Discharge permits and monitoring required.	High capital, low O&M cost.
	Onsite Discharge	Aquifer Reinjection	Effective discharge method. Injection wells susceptible to clogging if improperly designed.	Injection well permits and monitoring required.	High capital, low O&M cost.



Process option eliminated from further analysis.

**TABLE 11-6 (continued)**  
**SUMMARY OF DETAILED SCREENING OF**  
**TREATMENT TECHNOLOGIES AND PROCESS OPTIONS**

SOIL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
No Action	None	Not Applicable	Does not achieve remedial objectives.	Not applicable.	None.
Institutional Controls	Access Restrictions	Deed Restrictions	Effectiveness depends on long-term implementation. Does not reduce contamination.	Legal action may be necessary. Enforcement/monitoring difficult.	Negligible cost.
		Site Fencing	Does not reduce contamination but will limit site access.	Site already fenced.	None.
	Monitoring	Monitoring Surface Water Runoff	Useful for documenting conditions; does not reduce risk by itself.	Alone, not acceptable to local/public authorities.	Low capital, moderate O&M cost.
		RCRA Cap	Effective in preventing exposure. Does not reduce contamination. Seals contaminants in place.	Readily implementable using conventional equipment. impossible to develop site.	Moderate capital cost.
Containment	Capping	Asphalt Cap	Effective in preventing exposure. Does not reduce contamination but seals it in place.	Readily implementable using conventional equipment. Site could be developed where required.	Low-moderate capital cost. Some O&M costs if decay occurs.
		Concrete Cap	As above.	As above but site would be more difficult to develop.	Moderate capital cost. Some O&M costs if decay occurs.
Removal	Soil Removal	Excavation	Effective and conventional technology.	Readily implementable using conventional equipment.	High capital cost only.
Treatment	Onsite	Rotary Kiln	Effective and proven technology. Temperature unnecessarily high for site contaminants.	Implementable, mobile units available. Approval process involved, but should not be complex.	High capital cost.
		Low Temperature Rotary Dryer	Effective for VOCs, non-volatile organics, and hydrocarbons.	Implementable; commercially available mobile units.	Moderate-high capital cost.
		Fluidized Bed	Has proven effective in destruction of organics.	Units are available.	Moderate-high capital cost.
		Infrared	Has proven effective in destruction of organics.	Units are available.	High capital cost.

 Process option eliminated from further analysis.

**TABLE 6 (continued)**  
**SUMMARY OF DETAILED SCREENING OF**  
**TREATMENT TECHNOLOGIES AND PROCESS OPTIONS**

SOIL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
Treatment (cont.)	Onsite	Advanced Electric Reactor	Effective in treating waste at the site including PCBs and inorganics.	Successful at pilot level. Mobile unit available.	High capital cost.
		Thermal Auger	Effective in treating soils contaminated with organics and hydrocarbons.	Implementable; mobile units available.	Moderate-high capital cost.
		Pyrolysis	Effective. Few full-scale applications to date.	Implementable and commercially available. Lengthy approval process.	Low-moderate capital cost.
	Biological	Land Farming	Effective for simpler hydrocarbons. Levels of more complex organics could be more difficult.	Readily implementable, but requires large open spaces and HDPE liners.	Moderate capital cost.
	Physical/Chemical	Fixation/Stabilization	Innovative, but reliable and effective technology.	Readily implementable; mobile treatment units available.	Moderate capital, low O&M cost.
	Solvent Extraction	Liquified Gas	Effective for removal of most organics. Does not remove inorganics.	Implementable. Limited applications to date.	Moderate-high capital cost.
		Extraction	Especially effective for removal of organics and hydrocarbons, oil and grease, and PCBs.	Implementable. Produces residual waste water stream which may need to be addressed.	Moderate-high capital and O&M cost.
	In-Situ Treatment	Soil Aeration	Effective at reducing wide range of organics, but not heavier hydrocarbons.	Readily implementable. Site may have to be done in many segments.	Moderate capital and O&M cost.
		Microbial Degradation	Technology not fully proven. Results in the complete oxidation of organic contaminants.	Readily implementable. Design criteria not currently established.	Moderate capital and O&M cost.

Process option eliminated from further analysis.

**TABLE 11-6 (continued)**  
**SUMMARY OF DETAILED SCREENING OF**  
**TREATMENT TECHNOLOGIES AND PROCESS OPTIONS**

SOIL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	EFFECTIVENESS	IMPLEMENTABILITY	RELATIVE COST
Treatment (cont.)	Offsite	RCRA Incineration (Kiln)	Effective for destruction of organic contaminants. Temperatures unnecessarily high for site contaminants.	Capacity of approved RCRA facilities is limited. Transportation accidents are possible.	High capital cost.
		Low Temperature Thermal Treatment	Effective for VOCs, non- volatile organics and hydrocarbons.	Facilities are available. Transportation accidents are possible.	High capital cost.
Disposal	Offsite Disposal	Permitted Landfill	Effective. Not perma- nent solution.	Readily implementable. Transportation accidents are possible.	Moderate-high cost.
	Onsite Disposal	Permitted Landfill	Effective in reducing exposure. Does not reduce contamination but seals it from the environment.	Readily implementable. Large portion of site would not be available for development.	Moderate capital cost.



Process option eliminated from further analysis.

**Table 11-7. Selected Representative Technologies**

ENVIRONMENTAL MEDIA	GENERAL RESPONSE ACTION	AVAILABLE REMEDIAL TECHNOLOGY AND PROCESS OPTIONS
GROUNDWATER	No Action	None
	Institutional Controls	Groundwater Use Restrictions Groundwater Monitoring
	Collection	Extraction Wells
	Treatment: Onsite	Chemical/Physical: Carbon Adsorption Air Stripping Tower Multi-Media Filter
	In-situ	Microbial Degradation Air Sparging/Soil Vapor Extraction
	Offsite	Wastewater Treatment Plant (WTP)
	Discharge: Onsite	Infiltration Gallery
	Offsite	Direct Discharge to Willoughby Bay

## **12.0 DEVELOPMENT AND DETAILED ANALYSIS OF ALTERNATIVES**

### **12.1 Development of Alternatives**

Remedial alternatives are developed from the list of process options to meet the remedial response objectives. The remedial technologies/process options retained for further analysis are listed in Table 12-1. The individual technologies are combined to provide remedial alternatives to protect human health and the environment. A description of the remedial technologies used to develop remedial alternatives for QADSY follows.

#### **12.1.1 Summary of Groundwater Remedial Technologies**

The following remedial technologies prevent exposure to contaminated groundwater by managing contaminant migration.

##### **12.1.1.1 No Remedial Action - Long-Term Monitoring**

The limited action alternative for groundwater leaves the groundwater in its present condition, and long-term monitoring is the only action implemented. This alternative is used as a baseline for comparison with other remediation technologies. The risk assessment developed for the RI defines the level of risk associated with this limited action alternative.

Groundwater samples from monitor wells would be collected and analyzed for the contaminants of interest to determine the contaminant concentrations versus time, the spatial extent of the contaminant plume, and the location of potential receptors.

##### **12.1.1.2 No Remedial Action - Water Use Restrictions**

This institutional action involves implementing water use restrictions to prevent the use of the contaminated groundwater as a potable water source. The City of Norfolk currently has restrictions placed on the water table aquifer, including use of the groundwater as a potable water source by law. These restrictions prevent the possibility of nearby residences or businesses becoming potential receptors, fulfilling the goal of this technology; i.e., this remedial technology is currently in use.

##### **12.1.1.3 Groundwater Extraction/Pumping**

This technology is performed by removing contaminated groundwater via an extraction well or series of wells or interceptor trenches. Groundwater is then: 1) pumped to an onsite holding tank for later transport to offsite treatment, 2) pumped directly into an onsite treatment unit, or 3) pumped directly to storm drains discharging to Willoughby Bay.

Due to aquifer depth, constructing an interceptor trench would require open excavation to a depth of 30 to 45 feet deep. The depth of excavation makes this remedial technology more

difficult to implement than extraction wells. Therefore, extraction wells are considered the representative groundwater removal technology for developing alternatives.

#### 12.1.1.4 Onsite Treatment: Carbon Adsorption

Carbon adsorption is an effective treatment for VOCs removal. The process involves bringing the waste stream into contact with carbon in packed beds; the carbon adsorbs most VOCs as the contaminated water passes through the bed. When the carbon reaches its maximum adsorption capacity, it is replaced by fresh or regenerated carbon. Spent carbon is regenerated by the carbon supplier. However, due to the high cost of carbon and spent carbon regeneration, this technology may not be cost-effective alone.

#### 12.1.1.5 Onsite Treatment: Air Stripping

Air stripping is an effective process that removes VOCs from contaminated groundwater by transferring VOCs from a liquid stream to an air stream. Air stripping is commonly performed using a packed tower equipped with an air blower. The water stream flows down through the packing while the air flows upward; the air is exhausted through the top of the tower for treatment, if necessary. As a result of the process, VOCs tend to leave the aqueous stream for the gas phase.

#### 12.1.1.6 In-Situ Microbial Degradation

The bioremediation technology reinjects treated groundwater from the extraction wells, enriching the indigenous microbial population with nutrients. The effluent is then reinjected, enhancing in-situ microbial degradation and creating a closed-loop system. Periodic monitoring is performed to ensure that the enriched microorganisms are degrading contaminants effectively.

#### 12.1.1.7 Offsite Treatment at Industrial Waste Treatment Plant (IWTP)

After the QADSY groundwater is collected and treated for VOCs, the water is transported offsite by truck to the Naval Base IWTP. Groundwater collected during the pump test was accepted at the facility with limited testing for indicator parameters; therefore, it is assumed that this technology should not involve in-depth permitting requirements, such as the Virginia Pollutant Discharge Elimination System (VPDES) permit described below.

#### 12.1.1.8 Infiltration Gallery

Infiltration galleries are used in conjunction with in-situ technologies such as microbial degradation or soil flushing/washing. Treated groundwater is evenly sprayed over infiltration galleries at the site. The infiltration gallery serves as a filter and also enhances the biodegradation of any remaining contaminants. Permits may be needed to install infiltration galleries.



#### 12.1.1.9 Direct Discharge to Willoughby Bay

Treated groundwater is discharged directly to Willoughby Bay via existing storm sewers. Facilities would consist of a pumping station and a discharge pipe. VPDES permit requirements will have to be met.

#### 12.1.1.10 Air Sparging/Soil Vapor Extraction

Air sparging wells are used in conjunction with air extraction wells to remove VOCs from both groundwater and adjacent soils. VOCs in both the groundwater and soil are transferred into an air stream that is then removed by extraction wells. The VOC-laden air flow is treated and discharged.

### 12.2 Assembly of Alternatives

CERCLA, as amended by SARA, requires that at least one remedial alternative be developed in each of the following categories, to the extent possible:

- 1) A no-action alternative.
- 2) An alternative that involves waste containment with little or no treatment.
- 3) A treatment alternative that reduces the toxicity, mobility, or volume of the contaminants or contaminated media.
- 4) An alternative that completely and permanently treats the waste and eliminates the need for long-term monitoring.

By combining the selected technologies listed in Table 12-1, five alternatives were developed for this FS to address the remedial action objectives and meet the SARA guidance categories. These five alternatives are presented in Table 12-2.

### 12.3 Evaluation Criteria

Nine evaluation criteria serve as the basis for conducting the detailed analysis. The following five criteria represent the primary criteria that the analysis takes into account for technical, cost, institutional, and risk concerns:

- Short-term effectiveness
- Long-term effectiveness
- Reduction of mobility, toxicity, or volume
- Implementability
- Cost

The following two threshold criteria relate directly to statutory findings that must ultimately be made in the Record of Decision (ROD):

- Compliance with ARARs
- Overall protection of human health and the environment

The last two criteria are normally evaluated following review and comment on the RI/FS report and are addressed once a final decision is made and the ROD is prepared:

- State acceptance
- Community acceptance

Community acceptance may not be an applicable criterion for the QADSY due to the location of the site on Norfolk Naval Base and because the site is not a National Priorities List (NPL) site.

The nine evaluation criteria encompass statutory requirements and technical, cost, and institutional considerations that EPA's program has determined appropriate for a thorough evaluation of alternatives. Each of the nine evaluation criteria is further divided into specific factors for a complete analysis of the alternatives. These criteria and corresponding factors are discussed in the following sections.

### **12.3.1 Short-Term Effectiveness**

This evaluation criterion addresses the remedial alternative's effect on human health and the environment during the construction and implementation of the remedial action. The implementation phase of a remedial alternative is completed once remedial response objectives are met. The short-term effectiveness is based on the following four factors:

- The potential risk to the community
- The potential risk to the workers implementing the remedial actions
- The potential for adverse impacts on the environment due to implementing the remedial action
- The time required to meet the remedial response objectives

### **12.3.2 Long-Term Effectiveness**

This evaluation criterion addresses the results of a remedial alternative in terms of the risk remaining at the site after remedial response objectives have been met. The following factors characterize the potential remaining risk at the site following completion of the implementation phase:

- The magnitude of risk remaining due to untreated waste or treatment residuals following the completion of the remedial alternative
- The adequacy and reliability of controls that are used to manage untreated wastes or treatment residuals remaining at the site

### 12.3.3 Reduction of Mobility, Toxicity, or Volume

This evaluation criterion assesses the level to which the remedial alternative reduces risk by destroying toxic contaminants, reducing the total mass of contaminants, reducing the total volume of contaminated media, and/or the irreversible reduction of the contaminants' mobility. The specific factors considered in evaluating a remedial alternative are:

- The treatment processes the remedy will employ, and the materials they will treat
- The amount of hazardous materials that will be destroyed or treated, including how the principal threat(s) will be addressed
- The degree of expected reduction in mobility, toxicity, or volume measured as a percentage of reduction (or order of magnitude)
- The degree to which the treatment will be irreversible
- The type and quantity of treatment residuals that will remain following treatment
- Whether the alternative would satisfy the statutory preference for treatment as a principal element

### 12.3.4 Implementability

This criterion refers to the technical and administrative feasibility of implementing an alternative, and the availability of various materials and services required during its implementation. The following factors must be considered during the implementability analysis:

- Technical Feasibility: The relative ease of implementing or completing a remedial alternative considering physical constraints and the previous use of established technologies. The following should be considered:
  - Ability to construct the alternative
  - Reliability, or the ability of a technology to meet specified process efficiencies or performance goals
  - Ease of undertaking future remedial actions that may be required
  - Ability to monitor the remedy's effectiveness
- Administrative Feasibility: Activities needed to coordinate with other offices and agencies (e.g., obtaining permits for offsite activities or rights-of-way and easements required for construction).
- Availability of Services and Materials: The availability of the technologies (materials or services) required to implement an alternative. The following items should be considered:
  - Availability of adequate offsite treatment, storage capacity, and disposal services
  - Availability of necessary equipment, specialists, and provisions to ensure any necessary additional resources
  - Timing the availability of technologies under consideration

- Availability of services and materials, plus the potential for obtaining competitive bids that may be particularly important for innovative technologies

### 12.3.5 Cost

A cost estimate for each remedial alternative is developed in accordance with procedures in the Remedial Action Costing Procedure Manual (EPA, 1988). Cost calculations for all five detailed alternatives are included in Appendix Q.

#### 12.3.5.1 Capital Costs

Capital costs consist of direct (construction) and indirect (nonconstruction and overhead) costs. Direct costs include expenditures for the equipment, labor, and materials necessary to install remedial actions. Indirect costs include expenditures for engineering, financial, and other services that are not part of actual installation activities but are required to complete the installation of remedial alternatives. Costs that must be incurred in the future as part of the remedial action alternative are identified and noted for the year in which they will occur.

Direct capital costs may include the following:

- Construction costs for materials, labor, and equipment required to implement remedial action
- Equipment costs for remedial action and service equipment necessary to remain at the site until the remedy is complete
- Land and site development costs
- Buildings and service costs of process and nonprocess buildings, utility connections, purchased services, and disposal costs
- Relocation expenses of temporary or permanent accommodations for affected nearby residents
- Disposal costs for transporting and disposing of waste material such as drums and contaminated soil

Indirect capital costs, which are usually calculated as a percentage of direct capital costs, may include the following:

- Engineering expenses for administration, design, construction supervision, drafting, and treatability testing
- License or permit costs to obtain licenses and permits for installing and operating offsite activities

- Startup and shakedown costs incurred during remedial action startup
- Contingency allowances to cover costs resulting from unforeseen circumstances, such as adverse weather conditions, strikes, and inadequate site characterization

#### 12.3.5.2 Annual Operations and Maintenance (O&M) Costs

Annual O&M costs are post-construction costs necessary to ensure the continued effectiveness of a remedial action. The following annual O&M cost components are considered:

- Operating labor costs that cover wages, salaries, training, overhead, and fringe benefits associated with the labor needed for post-construction operations
- Maintenance materials and labor costs for labor, parts, and other resources required for routine maintenance of facilities and equipment
- Costs of items such as chemicals and electricity for treatment plant operations, water and sewer services, and fuel
- Costs to treat or dispose of residuals such as sludges from treatment processes or spent activated carbon
- Sampling costs, laboratory fees, and professional fees
- Costs associated with the administration of remedial action O&M not included under other categories
- Costs of such items as liability and sudden accidental insurance, real estate taxes on purchased land or rights-of-way, licensing fees for certain technologies, and permit renewal and reporting costs
- Annual payments into escrow funds to cover costs of anticipated replacement or rebuilding of equipment and any large unanticipated O&M costs
- Rehabilitation costs for maintaining equipment or structures that wear out over time
- Costs of periodic site reviews that are conducted at least every 5 years if wastes above health-based levels remain at the site

#### 12.3.5.3 Present Worth Analysis

A present worth analysis is developed to evaluate expenditures that occur over different time periods by discounting all future costs to the current year. This allows the cost of remedial action alternatives to be compared on the basis of a single figure representing the amount of money that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life. A 15-year performance

period is assumed for present worth analyses with the exception of Alternative 1 which is 30 years. A discount rate of 5 percent is used for the base calculations.

#### 12.3.5.4 Cost Sensitivity Analysis

After the present worth of each remedial action alternative is calculated, individual costs are evaluated through a sensitivity analysis. The sensitivity analysis assesses the effect that variations in specific assumptions associated with the design, implementation, operation, discount rate, and effective life of an alternative have on the estimated cost of the alternative.

A sensitivity analysis is considered for the factors that significantly change overall costs of an alternative with only small changes in their values, particularly those factors that have a high degree of uncertainty associated with them.

The following factors are considered in conducting the sensitivity analysis:

- The effective life of a remedial action
- The O&M costs
- The duration of cleanup
- The volume of contaminated material, given the uncertainty about site conditions
- The discount rate (a range of 3 to 10 percent is used to investigate uncertainties)

The results of a sensitivity analysis are discussed during the comparison of alternatives. Areas of uncertainty that may have a significant effect on the cost of an alternative are highlighted, and a rationale is presented for selection of the most probable value of the parameter.

Cost estimates provided for each alternative are intended to reflect actual costs with an accuracy of -30 to +50 percent, consistent with the EPA RI/FS guidance.

#### 12.3.6 Compliance with ARARs

This evaluation criterion determines whether each alternative meets all the federal and state ARARs selected in this RI/FS process (Appendix O). When an ARAR is not met, the basis for a waiver is discussed. The following specific ARARs are evaluated for compliance:

- Chemical-specific ARARs
- Action-specific ARARs

No location-specific ARARs were identified for the QADSY site.

#### 12.3.7 Overall Protection of Human Health and the Environment

This evaluation criterion serves as a final check to assess whether each alternative provides adequate protection to human health and the environment. It draws on the overall protection drawn from assessments conducted on short-term effectiveness, long-term effectiveness, and compliance with ARARs.

### **12.3.8 State Acceptance**

This assessment evaluates the technical and administrative issues/concerns the Commonwealth of Virginia may have regarding each of the alternatives. This criterion will be addressed in the ROD once comments on the RI/FS report and the proposed alternative(s) have been received.

### **12.3.9 Community Acceptance**

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with state acceptance, this criterion is normally addressed in the ROD once comments on the RI/FS report and the proposed alternative(s) have been received, although this criterion may not be applicable to the QADSY.

## **12.4 Individual Analyses of Alternatives**

Each remedial alternative developed in Section 12.1.1 is evaluated in detail in this section, including:

- A detailed description identifying all the components necessary for evaluation
- A detailed analysis considering the nine evaluation criteria outlined in Section 12.2

### **12.4.1 Alternative 1: No-Action/Institutional Controls**

This no remedial action alternative consists of implementing monitoring to determine access and exposure to contaminated groundwater. No remedial actions that result in the treatment, containment, or removal of the contaminated media will be implemented under this alternative. In addition, this alternative would require continuation of current water use restrictions.

The elements necessary to implement the no-action alternative follow:

- Installing two shallow and three deep monitor wells
- Collecting groundwater samples at 11 wells
- Additional contaminant transport modeling
- Periodically evaluating public health

#### **12.4.1.1 Detailed Description**

A long-term (e.g., 30 years) groundwater monitoring program will provide data necessary to determine the extent of contaminant migration over time. Eleven wells, six existing and five new, will be monitored quarterly for VOCs. Five new monitor wells will be constructed at locations determined by modeling: three within the plume boundaries and two downgradient. Two of the new wells will be approximately 35 feet deep, and three will be approximately 45 feet deep to detect vertical migration of contaminants, if present.

Quarterly groundwater monitoring data will be evaluated after the first two years. If the variability between sampling events is low, the sampling frequency will be reduced to semi-annual. Annual monitoring can be considered after a five-year period.

Well monitoring data will be reviewed every five years. Additional modeling will be performed to determine contaminant migration patterns. A public health evaluation will also be performed to determine if new receptors are present, or if contaminant concentrations have increased at previously identified receptors.

Water use restrictions to prevent the use of the shallow aquifer as a potable water supply would remain in effect in accordance with City of Norfolk laws.

#### 12.4.1.2 Detailed Analysis

The no-action alternative, which includes groundwater monitoring and water use restrictions, was assessed against the seven evaluation criteria described in the most recent RI/FS guidance from EPA (October 1988). Restoration time-frame for Alternative 1 is approximately 30 years and can vary significantly due to groundwater flow velocity, natural degradation, and extent and degree of contamination. The results of this assessment are presented in the following paragraphs.

##### Short-Term Effectiveness

No treatment technologies have been proposed for the water in this no-action alternative; therefore, the only safety concern would involve possible worker exposure to contaminated materials onsite during sampling efforts. Personal protective gear for workers during well installation and sampling will help minimize associated risks.

Even though water use restrictions are associated with this no-action alternative, contaminants may continue to be released into the surficial aquifer and migrate offsite.

##### Long-Term Effectiveness

This alternative's long-term effectiveness would be influenced by the fact that risks over a period of time would still exist due to potential use of groundwater as a potable supply, despite enforcement of and advice about water use restrictions. The community would not be completely protected due to this potential exposure. The actual risk associated with groundwater consumption is discussed in the risk assessment.

The long-term effectiveness of restricting water use is similar to the short-term (i.e., the exposure pathway of contaminants is minimized). It is expected that contaminants could eventually leach from the soil over time, although the exact extent of leachate generation is not known. Therefore, additional modeling will be necessary to accurately estimate the contaminant reduction over time.



Reduction of Mobility, Toxicity, or Volume

Because none of the contaminants in the groundwater will be destroyed, removed, or treated in this alternative, contaminant mobility will remain unchanged. The toxicity levels of the contaminant will slowly degrade through time due to natural biodegradation. No volume reduction of the contaminated media will occur with the implementation of monitoring and water use restrictions.

Implementability

Continued water use restrictions would be easily implemented: VDOH currently has them in place, and no known potable water wells exist in the vicinity. In the event that groundwater is still used from a downgradient well, an alternate water source will be required. Monitoring could be implemented without difficulty: coordinating with regulatory agencies would not be required. The services and materials required for well installation and monitoring are readily available.

Cost

The capital and annual O&M costs for monitoring and water use restrictions are approximately \$34,991 and \$28,500, respectively. A periodic O&M cost of \$9,000 every five years would be required to conduct a site review and public health evaluation. This is equivalent to a total present worth cost over 30 years of approximately \$884,195. See Table Q-1 in Appendix Q for cost details.

Compliance with ARARs

The no-action alternative would not comply with the selected ARARs because VDEQ standard exceedances would still exist in the water table aquifer.

Overall Protection of Human Health and the Environment

Implementing the no-action alternative would provide overall protection to human health by eliminating exposure to groundwater through groundwater use restrictions. The alternative would not provide overall protection to the environment because the contaminants are naturally free to migrate.

## 12.4.2 Alternative 2: Groundwater Collection, Treatment, and Onsite Discharge

The elements necessary to implement this alternative are:

- Locating and installing 33 extraction wells
- Constructing and operating a groundwater treatment system
- Locating and installing pressurized conveyance piping
- Locating a discharge point for treated water into Willoughby Bay

### 12.4.2.1 Detailed Description

A series of groundwater recovery wells (33 are estimated) will capture the QADSY contaminant plume. After additional transport modeling, the wells would be located along the west boundary of the site. Considering the average pump rate obtained during the pump test, it is estimated that a maximum rate of 10 gallons per minute (gpm) can be obtained from one recovery well. The exact number of wells, their locations, and effective pump rates will be determined from additional pump tests and groundwater modeling performed during the predesign phase.

The extracted groundwater will be conveyed under pressure via aboveground pipe to the treatment system. Influent VOC concentrations (i.e., PCE, TCE, DCA, and carbon tetrachloride) are estimated to be the representative concentration, on the basis of isoconcentration contours of the VDEQ surface water standard.

Extracted groundwater will be treated by VOC volatilization by air stripping. Discharge would be through an air stripper for VOC removal. Effluent from the stripping tower will be monitored weekly prior to discharge to surface waters (i.e., Elizabeth River) via an existing storm sewer line. A National Pollutant Discharge Elimination System (NPDES) permit would be required for direct discharge. Five times the plume volume is estimated to be required to reduce concentrations to remedial action levels. This volume would be treated over a 3- to 12-year period depending on the groundwater extraction rates as calculated in Appendix P. This estimate can vary significantly due to factors such as volume and velocity of groundwater flow, extent and degree of contamination.

The air emissions from the air stripping tower are estimated to contain less than a total of 0.005 pounds per day (lb/hr) of VOCs. The VOC emission will be significantly less than the Virginia Air Quality limits of 4.0 pounds per hour (lb/hr) for a fixed source. Therefore, no air pollution controls are necessary to meet ARARs.

### 12.4.2.2 Detailed Analysis

#### Short-Term Effectiveness

No significant environmental impacts are to be expected during construction or implementation of this alternative.

The groundwater remediation system described would result in some small-scale fugitive volatile organic emissions as a result of the air-stripping activities. Generally, the system would be installed using normal construction practices, drilling equipment, etc. A comprehensive site safety plan would be prepared prior to initiating construction. The removal of VOCs will begin immediately after this system starts to operate.

Human health (including workers) and the environment will be protected from any adverse risks by prudent safety measures.

#### Long-Term Effectiveness

When the pump-and-treat activities are complete, groundwater concentrations for the contaminants of interest associated with the QADSY sources are not anticipated to exceed action levels.

If no source control removal or treatment actions are performed, contaminated soil would remain onsite (in place) after the treatment actions; however, the concentrations would be reduced over time. If the soil is not disturbed, no significant risk is anticipated. A reevaluation of hazards associated with any excavation or creation of new exposure routes would have to be assessed every five years.

#### Reduction of Mobility, Toxicity, or Volume

The treatment process will remove the VOCs from the groundwater and allow them to dissipate into the atmosphere. This is considered an irreversible process because the contaminants are extremely diluted in the atmosphere. The toxicity of the contaminants in the groundwater will be reduced because of their removal. The contaminants in the atmosphere will eventually break down through natural processes such as photo-oxidation. The volume of contaminated groundwater will be reduced by not allowing its continued migration at concentrations above action levels. The mobility of contaminants in the groundwater will be restricted to the area influenced by the extraction wells during the pump-and-treat phase.

#### Implementability

This alternative has no anticipated technical difficulties associated with its construction or operation. All materials and services for these remedial technologies are readily available.

Several activities are proposed for the remedial design phases: (1) conduct additional pump tests to accurately determine number, size, depth, and location of recovery wells, (2) expand groundwater transport model (i.e., predict areal and vertical extent of plume), (3) develop accurate design of the groundwater remediation treatment system, and (4) monitor underground contaminant concentrations.

The acquisition of permits for the location and construction of treatment system elements such as injection wells, extraction wells, treatment vessels, and associated piping; if any such permits were required, will not be any more difficult than at other military facilities.

### Cost

The estimated capital cost of this alternative is approximately \$456,475, the estimated annual O&M cost is \$136,260, and an estimated periodic cost to perform the site review and public health evaluation every five years is \$9,000. The present worth cost over 15 years is estimated to be \$2,902,236 based on a 5 percent discount rate. See Table Q-2 in Appendix Q for cost details.

### Compliance with ARARs

The contaminant removal rate from this treatment system should reach operational equilibrium within a relatively short period of time after being activated. Once action levels have been achieved in the groundwater and the pump-and-treat phase is completed, groundwater concentrations will not exceed the chemical-specific ARARs. All treated groundwater would be discharged into Willoughby Bay at levels below chemical-specific ARARs for all organic chemicals. It is assumed that removal effectiveness for all indicator chemicals is similar and that treatment to below ARARs is achievable.

This alternative will also meet the action-specific ARARs selected for surface water discharges, NPDES Effluent Standards and/or Limitations. Emissions from the air stripping towers are also estimated not to exceed action-specific ARARs for air emissions.

### Overall Protection of Human Health and the Environment

This alternative is considered to provide adequate protection to downgradient groundwater receptors during the implementation phase. Once treatment is completed (i.e., action levels have been obtained), the risk to human health is considered to be the same as the risk associated with background levels that currently exist at the site.

## **12.4.3 Alternative 3: Groundwater Collection, Pretreatment, and Offsite Treatment**

### **12.4.3.1 Detailed Description**

This alternative consists of the same groundwater recovery and treatment system as Alternative 2. The contaminated groundwater will be pretreated by VOC volatilization by air stripping so that the effluent can be discharged to an IWTP, such as the Norfolk Naval Base Industrial IWTP, via truck transport. This alternative, therefore, eliminates the need for direct discharge to Willoughby Bay. The contamination would be treated over a 3- to 12-year period, depending on the groundwater extraction rates as calculated in Appendix O. This estimate can vary significantly due to factors such as volume and velocity of groundwater flow, extent and degree of contamination.

### 12.4.3.2 Detailed Analysis

Because this alternative consists of the same groundwater recovery system, volatilization of VOCs as Alternative 2, both short- and long-term effectiveness are comparable. The same reduction of mobility, toxicity, and volume is also achieved. This alternative will provide overall protection of human health and the environment and will comply with all ARARs for water quality. The major differences between the two alternatives are in the implementation and cost, as discussed below.

#### Implementability

The ability to implement, construct, and operate the groundwater recovery system and the VOC volatilization system is relatively easy, as discussed under Alternative 2. However, difficulties in obtaining approval for discharge to the IWTP may render this alternative invalid. The estimate flow rate of 330 gpm (or 475,200 gallons per day) may exceed existing capacity of the IWTP.

#### Cost

The estimated capital cost of this alternative is approximately \$446,475, the estimated annual O&M cost is \$318,380, and an estimated periodic cost to perform the site review and public health evaluation every five years is \$9,000. The present worth over 15 years is an estimated \$5,936,299 based on a 5 percent discount rate. See Table Q-3 in Appendix Q for cost details.

### **12.4.4      Alternative 4: Collection/Onsite Treatment/Onsite Discharge/In-Situ Treatment**

This alternative consists of the same groundwater recovery system (i.e., air stripping) as Alternative 2, but includes additional in-situ treatment by biological degradation to decrease remediation time. In addition to the recovery and treatment equipment outlined under Alternative 2, Alternative 4 will require installing and operating biologic nutrient and catalyst control units and infiltration gallery and manifolds as part of the design effort a Biofeasibility study would be required. All treated water will be discharged into the surficial aquifer so that no water discharge to Willoughby Bay or Elizabeth River will occur.

#### **12.4.4.1 Detailed Description**

The treatment system employed in Alternative 2 would be used; the extracted water is passed through an air stripper to remove the VOCs. Instead of direct discharge to Willoughby Bay, the treated water from the air stripper would be discharged into an onsite infiltration gallery to stimulate the biodegradation of the chlorinated solvents (i.e., TCE and PCE). The infiltration gallery consists of a 12-foot by 12-foot by 3-foot trench filled with gravel into which treated water is discharged. This gallery acts as a trickling filter designed to maximize the surface area of the water in contact with air for biological degradation purposes. The in-situ biological treatment relies on either a soils indigenous microbial population, or an introduced population to degrade the contaminants of interest. In either case, nutrients, catalysts, and

terminal electron acceptors may be added to the stream to promote degradation. The treatability study will qualify the exact environment needed to maximize degradation. The water would be discharged into the infiltration gallery through a manifold branching out into several pipes designed to maximize the gallery area usage thus maximizing the degradation of any existing compounds. Additionally, the microbial population would be allowed to penetrate into the most contaminated portion of the aquifer, forming a large subsurface bioreactor in the saturated zone. The infiltrated water will steepen the local hydraulic gradient, which will subsequently increase groundwater velocity toward the extraction wells. Increased groundwater velocity will decrease the total remediation timeframe.

The placement of the extraction wells will be finalized during the design stage of the project. Additionally, a complete evaluation of the full extent of the plume and groundwater chemistry will need to be undertaken. The contamination would be treated over a 3- to 12-year period, depending on the groundwater extraction rates as calculated in Appendix O. This estimate can vary significantly due to factors such as volume and velocity of groundwater flow, extent and degree of contamination.

#### 12.4.4.2 Detailed Analysis

##### Short-Term Effectiveness

No significant environmental impacts are to be expected during construction or implementation of this alternative.

The groundwater remediation system described would result in some small-scale fugitive volatile organic emissions as a result of the air-stripping activities. Generally, the system would be installed using normal construction practices, drilling equipment, etc. A comprehensive site safety plan would be prepared prior to initiating construction.

Remedial objectives would be achieved when contaminant levels were consistently below cleanup standards for the groundwater. Bioremediation, if successful, will accelerate groundwater VOC cleanup.

##### Long-Term Effectiveness

When this alternative is complete, VOC levels in the water are expected to be permanently reduced because bioremediation results in the destruction of contaminants. The air stripping and bioremediation systems could be discontinued once VOC action levels were attained. Because the materials will be destroyed or removed from the groundwater following system shut-down, only a groundwater monitoring program would be required to evaluate continuing potential hazards at the site.

### Reduction of Toxicity, Mobility, and Volume

The biorestorative process irreversibly destroys contaminants rather than stabilizing them or transferring them to another medium. VOC toxicity and volume will be permanently reduced.

### Implementability

The technical feasibility of constructing and installing air-stripping treatment presents no problems: the technology is well developed and readily available. Groundwater pump-and-treat is effective and frequently used.

The technical feasibility of bioremediation is not yet fully determined. The piping, feed system, and discharge infiltration gallery systems are all easily installed; whether degradation occurs as a result is not easily assessed until a biofeasibility study is completed. Preliminary indications suggest that the environment may be favorable for in-situ biodegradation, permeabilities at the site are fairly high, the aquifer is fairly homogeneous, the groundwater chemistry seems fairly normal, the sources are fairly well defined, and perhaps most importantly, some natural degradation may already be taking place in the groundwater. If the biofeasibility study suggests that bioremediation is unsuitable, alternative methods of remediation can be easily implemented.

The administrative feasibility of the alternative depends on the acceptance by the Navy and regulatory agencies of the installation of the infiltration gallery at the site (i.e., what water quality is required to allow treated groundwater to be discharged) and whether all water discharged needs to be recovered. Both criteria can be incorporated into any final design, but it is likely to increase costs. Burying the extraction and recharge piping may allow some use of the site, but two considerations need to be addressed for this option: (1) the surface soils seem to harbor the majority of the contaminants, and (2) an increase in cost would result.

The equipment and services needed to implement each step in the alternative are readily available from a number of vendors.

### Cost

Estimated capital costs for this alternative are approximately \$503,750. Monthly O&M costs will be in the order of \$136,260, but will be reduced significantly when the bioremediation system is no longer needed. The estimated periodic cost to perform site review and public health evaluation every five years is \$9,000. The present worth over 15 years is an estimated \$2,963,694 based on a 5 percent discount rate. See Table Q-4 in Appendix Q for cost details.

### Compliance with ARARs

This alternative is expected to meet all chemical-specific ARARs for the groundwater. Action-specific ARARs that may need to be negotiated include: the quality of water to be reinjected into the aquifer, whether all reinjected water needs to be reclaimed and air emission standards for the air-stripping tower. No location-specific ARARs are known to exist.

### Overall Protection of Human Health and the Environment

This alternative is considered to provide adequate protection to downgradient groundwater receptors during the implementation phase. Once treatment is completed (i.e., action levels have been obtained), the risk to human health is considered to be the same as the risk associated with the current background levels. Biotreatment, if successful, will completely destroy contaminants and may continue to do so after surface treatment is completed, offering better protection of the environment.

#### 12.4.4.3 Detailed Analysis

##### 1. Short-Term Effectiveness

No Significant environmental impacts are to be expected during construction or implementation of this alternative.

The groundwater remediation system described would result in some small-scale fugitive volatile organic emissions as a result of the air-stripping activities. Generally, the system would be installed using normal construction practices, drilling equipment, etc. A comprehensive site safety plan would be prepared prior to initiating construction.

Remedial objectives would be achieved when contaminant levels were consistently below cleanup standards for the groundwater. Bioremediation, if successful, will accelerate groundwater VOC cleanup.

##### 2. Permits

The acquisition of permits for the location and construction of treatment system elements such as extraction wells, treatment vessels, and associated piping; if any such permits were required, will not be any more difficult than at other military facilities. The permit regulations for infiltration galleries are unknown. Current regulations are unclear as to exact requirements; therefore, obtaining permits to operate the injection gallery is anticipated to require significant effort.

##### 3. Compliance with ARARs

The contaminant removal rate from this treatment system should reach operational equilibrium within a relatively short period of time after being activated.



## 12.4.5 Alternative 5: Air Sparging/Soil Vapor Extraction

### 12.4.5.1 Detailed Description

Air sparging wells are used in conjunction with air extraction wells to remove VOCs from both groundwater and adjacent soils. Contaminant free air is forced into the saturated zone below the areas of contamination. The contaminants dissolved in the groundwater and adsorbed on the adjacent soils are then removed into the advective and convective air phase, effectively simulating an in situ air stripping system. The stripped contaminants are transported in the air phase to the vadose zone, within the radius of influence of the vapor extraction well. The air flow goes from the vapor extraction well to an air-water separator (vapor removal) and then through an activated carbon vessel where any remaining VOCs will be removed before the air is vented to the atmosphere. The condensed water vapor removed by the air-water separator will be piped through an air stripper and an activated carbon vessel before it is discharged to a surface storm drain. Based on the "Soil Vapor Extraction/In-Situ Air Sparging Pilot test" conducted by Target Environmental Services, Inc. in June 1995.

The radius of influences at the QADSY site were separated into two areas (HM and FP) from the AS/SVE pilot studies. The vacuum radius of influence at the HM and FP areas is 70 feet and the AS radius is 25 feet. Eight AS wells and six SVE wells are required to effectively remediate the HM plume, and 75 AS wells and 33 SVE wells are required for the FP plume.

Due to system size, the number of AS/SVE wells would not be a viable alternative option. An alternative discussed with LANTDIV would position the AS and SVE wells on the downgradient edge of the plume paralleling the waterfront. This arrangement would provide a remediation zone prior to groundwater discharge to the Elizabeth River. The system at the FP would consist of approximately 22 AS wells and 13 SVE wells. A total of 30 AS and 19 SVE wells would be required to effectively remediate the two existing plumes.

### 12.4.5.2 Detailed Analysis

#### Short-Term Effectiveness

The removal of VOCs will begin immediately after this system starts to operate. The complimentary application of air sparging/soil vapor extraction will result in the accelerated removal of VOCs contaminants from both subsurface soils and groundwater. This type of system will have a faster impact on the quality of the downgradient groundwater versus other slower remedial technologies (i.e., pump and treat) on the basis of published research information.

#### Long-Term Effectiveness

The VOCs RGOs will not be exceeded in the groundwater in the long run. This is mostly due to the fact that both the groundwater and the soil are being treated in this alternative. This will prevent any future leaching of VOCs from untreated soils into clean groundwater.

### Reduction of Mobility, Toxicity, or Volume

All VOCs from both the soil and groundwater will be removed and dissipated into the atmosphere. The toxicity of the contaminants in both the groundwater and adjacent soil will be reduced because of their removal. Any remaining VOCs discharged into the atmosphere by this treatment system will be extremely dilute and will break down through natural processes such as photo-oxidation. The mobility of the contaminants will be reduced by their removal from both soil and groundwater. The volume of contaminated soil and groundwater will be reduced due to the simultaneous removal and treatment of both media.

### Implementability

The materials and services required for the implementation of this alternative are widely available. No serious technical difficulties are expected during the construction and operation phases of this system.

Several activities are proposed for the remedial design phase:

- Obtain soil boring samples to determine the presence, location, and concentration of contaminants in the soil.
- Expand groundwater transport model (i.e., predict horizontal and vertical extent of the plume)
- Conduct a small scale pilot test to develop design parameters for a full scale air sparging system.
- Monitor underground contaminant concentrations.

The acquisition of permits for the location and construction of treatment system elements (such as air injection wells, extraction wells, treatment vessels, and associated piping) if any such permits are required, will not be any more difficult than at other military facilities.

### Cost

The estimated cost for this alternative is approximately \$1,254,219. The estimate annual O&M cost is \$264,200 and an estimated periodic cost to perform the site review and public health evaluation every five years is \$9,000. The present worth cost over 15 years is estimated to be \$4,621,701 based on a 5 percent discount rate. See Table Q-5 in Appendix Q for cost details.

### Compliance with ARARs

The contaminant removal rate from this treatment system should reach operational equilibrium within a relatively short period of time after being activated. Groundwater concentrations are not expected to exceed chemical-specific ARARs once the treatment phase

is over due to the fact that both the soil and groundwater will have been remediated by this system. All treated groundwater from the air-water separator would be discharged into Willoughby Bay at levels below chemical-specific ARARs for all organic chemicals.

This alternative will also meet the action-specific ARARs selected for surface water discharges, NPDES effluent standards and/or limitations. Emissions from the system air stripper and extraction well exhausts are also estimated not to exceed action-specific ARARs for air emissions.

#### Overall Protection of Human Health and the Environment

This alternative will adequately protect downgradient receptors during the implementation stage. The risk to human health will be no different from that associated with natural background levels that currently exist at the site.

## **12.5 Comparative Analysis of Alternatives**

This section compares the five groundwater remediation alternatives. All alternatives are compared with respect to the seven evaluation criteria. Reasonable and relative variations within each criterion are discussed so that all alternatives are compared as a group. Final alternative selection is based on this comparative analysis.

### **12.5.1 Short-Term Effectiveness**

All alternatives (Nos. 2, 3, 4, and 5) are more effective in reducing aquifer contamination than the no remedial action alternative. In alternatives 2, 3, and 4, this is because contaminated groundwater is extracted from the surficial aquifer, treated, and discharged by three different means: surface water, WTP, and infiltration gallery. Alternative 5 effectively treats the contamination from the groundwater prior to discharge to the atmosphere. However, the no-action alternative may be equally effective in reducing exposure to contaminants if current water and land use restrictions are maintained.

Alternatives 2, 3, and 4 will have onsite emissions from air stripping and/or onsite discharge of treated water. Alternative 5 will have onsite emissions from vapor extractions. Alternative 1 will not affect the current exposure to workers and the community because no contaminated groundwater extraction will occur.

Alternative 4 will achieve remedial objectives quicker than Alternatives 2 and 3. The relative remedial rates cannot be determined until the completion of a Bioremediation/biological degradation/biological feasible study is conducted.

Alternative 5 does not include extraction of groundwater and has the least likelihood of uncontrolled contaminant release.

Alternative 1 will not meet the remedial response objectives over time.

### **12.5.2 Long-Term Effectiveness**

The alternatives, except the no-action alternative, remove contaminants from the site and do not leave any untreated waste or residuals that require managing to ensure an adequate level of protection.

The no-action alternative will effectively reduce the potential for exposure to contaminants but will not eliminate exposure over the long term. This alternative leaves the contaminants in place and requires management beyond the implementation phase.

### **12.5.3 Reduction of Mobility, Toxicity, or Volume**

Alternative 4 will provide the greatest degree of contaminant destruction and therefore the greatest degree of mobility, toxicity, and volume reduction. Alternatives 2 and 3 will also provide a similar reduction. However, Alternative 4 provides a greater degree of volume and mobility reduction due to the additional in-situ treatment of the VOCs in the area influenced by the extraction wells.

Alternatives 2, 3, and 4 provide hydraulic control of the Aquifer.

Alternative 5, through the removal of contaminants, vapors and extraction of air will provide a quick reduction in contaminant volume and therefore provide control of mobility, toxicity, and volume of contaminated groundwater.

Alternative 1 does not consist of any containment, collection, or treatment actions and will not reduce the mobility, toxicity, or volume of contaminants in the groundwater.

### **12.5.4 Implementability**

All of the remediation alternatives for groundwater are technically feasible. Each alternative can be constructed and operated on reliable technologies that are both effective and proven. Alternatives 2, 3, and 4 involve standard extraction and wastewater treatment processes with monitored discharge or disposal. The exception is Alternative 4, infiltration gallery with microbial degradation. However, until a biological treatability study is performed, the actual degradation rate and system parameters are unknown. Further, the operational permit process for the infiltration gallery is not well defined.

The no-action alternative for groundwater is easiest to implement because water and land use restrictions are already in place, and long-term groundwater monitoring and surface water runoff monitoring are easy to put in operation.

Implementation of the remediation alternatives from an administrative standpoint is not estimated to be a major concern because the QADSY is on Navy property. It is also surrounded by Navy property so rights-of-way and easements should not be a problem. Permits from the Virginia regulatory agencies would be required for any air emissions from stripping towers.

### 12.5.5 Cost

The present worth, capital, annual O&M, and periodic O&M costs for each alternative are presented in Table 12-3. Alternative 5 has the highest capital cost and the highest present worth.

A sensitivity analysis was performed for each alternative. The sensitivity of the present worth cost estimate to the following variables was assessed for each alternative:

- Discount rate ( $r = 3$  and 10 percent)
- Cleanup duration
- Contaminated media volume
- O&M cost
- Replacement cost

The results of the present worth cost sensitivity analyses are presented in Table 12-4 and discussed in the following paragraphs.

The discount rate was varied for those alternatives that have cost components that occur over a period greater than one year. Alternative 1 is more sensitive to the discount rate than the other alternatives because the O&M costs are a larger percentage of the overall costs.

The cleanup duration or time required to meet the remedial action objectives was varied for the alternatives. Cleanup was halved and doubled for Alternatives 2, 3, 4, and 5. The time period for Alternative 1 was not doubled because it is initially evaluated over a 30-year performance period. The alternatives present worth costs change by approximately 33 to 43 percent when cleanup is cut in half, and by approximately 61 to 80 percent when doubled.

The volume of contaminated groundwater impacts the present worth costs of Alternatives 2, 3, 4 and 5. The flow rates for the alternatives were reduced by half and doubled to determine the impact on present worth costs. Reducing the flow rate by half reduces the present worth value by approximately 29 to 44 percent. Doubling the flow rate similarly increases the present worth cost by approximately 57 to 87 percent. Both alternatives have similar sensitivity to a change in the groundwater flow rate.

The O&M costs for each alternative with O&M cost components were adjusted up and down by 20 percent to demonstrate the impact on the present worth costs. The relative degree of sensitivity of the present worth cost to changes in O&M cost reflects the same relative sensitivity of present worth costs to changes in the discount rate because the discount rate applies only the O&M costs.

The present worth costs were recalculated by considering the replacement of the capital expenditure items at half the performance period for those alternatives that have performance periods greater than one year. These present worth costs are presented in the last line of Table 12-4. Alternative 5 demonstrates the greatest sensitivity to the replacement cost because the capital expenditures are a greater portion of the alternative's present worth cost.

### **12.5.6 Compliance with ARARs**

Alternatives 2, 3, 4, and 5 will all meet chemical-specific ARARs following completion of the treatment phase. Alternative 1, however, will not meet ARARs because no remediation of the contaminants will occur and VDEQ exceedances will still exist in the upper aquifer. Treated groundwater under Alternatives 2 and 5 will be discharged into Willoughby Bay at levels below chemical-specific ARARs.

Action-specific ARARs will also be met by Alternatives 2, 3, 4, and 5. Alternatives 2, 3, and 4 are not expected to exceed action-specific ARARs for air emissions from the air stripping towers. Alternative 5 is not expected to exceed action-specific ARARs for air emissions from the vapor extraction system. Alternatives 2 and 5 will meet ARARs for surface water discharges, and Alternative 4 should meet ARARs for treated groundwater infiltration.

### **12.5.7 Overall Protection to Human Health and the Environment**

Alternatives 2, 3, 4, and 5 will provide adequate protection to human health and the environment following contaminated groundwater treatment. Once treatment is completed, the risk to human health will be the same as the risk associated with background levels that currently exist at the site. Contaminants will be completely destroyed, providing overall protection to the environment.

Alternative 1 will provide protection to human health by eliminating exposure to groundwater; however, the alternative will not be protective of the environment because contaminants will remain in place.

**Table 12-1****Remedial Technologies Retained for the QADSY Site****GROUNDWATER**

- No remedial action
- Groundwater use restrictions (already in place)
- Long-term groundwater monitoring
- Groundwater extraction
- Onsite treatment:
  - Carbon adsorption
  - Air stripping
- In-situ microbial degradation
- In-situ air sparging/soil vapor extraction
- Offsite treatment at wastewater treatment plant (WTP)
- Infiltration Gallery
- Direct discharge to Willoughby Bay

Table 12-2

## Remedial Alternatives Assembled for the QADSY Site

MEDIUM	ALTERNATIVE CATEGORY	ALT. NO.	REMEDIAL TECHNOLOGY
GROUNDWATER	No action/ Institutional Controls	1	Long-term monitoring Water use restrictions
	Collection/ Onsite treatment/ Offsite Discharge	2	Extraction wells Air stripping Discharge to Willoughby Bay
	Collection/ Offsite Treatment	3	Extraction wells Discharge to WTP
	Collection/ Onsite Treatment/ In-situ Treatment/ Onsite Discharge	4	Extraction wells Air stripping Infiltration gallery Microbial degradation
	Air sparging/soil vapor extraction	5	Air sparging wells Vapor extraction wells Carbon Adsorption Discharge to atmosphere



**Table 12-3****Present Worth Cost for Remedial Alternatives at the QADSY**

ALTERNATIVE	PRESENT WORTH	CAPITAL COST	ANNUAL O&M	PERIODIC O&M
<u>GROUNDWATER</u>				
1. No Remedial Action/Long-Term Monitoring	\$884,195	\$34,991	\$28,500	\$9,000
2. Groundwater Extraction, Onsite Treatment, and Discharge to Storm Drain	\$2,902,236	\$411,475	\$136,260	\$9,000
3. Groundwater Extraction, VOC Pretreatment, and Discharge to IWTP	\$5,936,299	\$411,475	\$318,380	\$9,000
4. Groundwater Extraction, Treatment, Infiltration, and Biologic Treatment	\$2,963,694	\$503,750	\$136,260	\$9,000
5. Air sparging/soil vapor extraction	\$4,621,701	\$1,254,219	\$264,200	\$9,000

Note: Costs are rounded off to the nearest \$100

Table 12-4

**Sensitivity of the Present Worth Costs to Different Factors for Remedial Alternatives at the QADSY**

FACTOR	ALTERNATIVES				
	1	2	3	4	5
Base (r = 5%)	\$884,195	\$2,902,236	\$5,936,299	\$2,963,694	\$4,621,701
r = 3 %	\$1,121,095	\$3,250,545	\$6,742,057	\$3,312,003	\$5,073,239
r = 10 %	\$553,106	\$2,282,852	\$4,502,700	\$2,344,309	\$3,756,152
1/2 x (duration of cleanup)		\$1,801,585	\$3,389,175	\$1,863,042	\$3,101,254
2 x (duration of cleanup)		\$4,962,569	\$10,721,304	\$5,024,026	\$7,416,112
1/2 x (volume of media)		\$1,838,611	\$3,349,142	\$1,900,069	\$3,272,982
2 x (volume of media)		\$5,029,487	\$11,110,611	\$5,090,944	\$7,252,135
80% of Base O&M	\$724,395	\$2,446,282	\$4,870,932	\$2,507,740	\$3,990,980
120% of Base O&M	\$1,043,995	\$5,182,007	\$7,001,665	\$3,419,648	\$5,252,444
Replacement	\$34,991	\$456,475	\$446,475	\$503,750	\$1,254,219

### 13.0 FS REFERENCES

EPA (US Environmental Protection Agency), October, 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Vendor CERCLA. Interim Final, EPA 540/G-89/004

Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall, New Jersey.

LANTNAVFACENGCOM, 1988, Installation Restoration Program Remedial Investigation - Interim Report, Naval Base, Norfolk, Virginia, LANTNAVFACENGCOM, Norfolk, Virginia.

## **Appendix A**

### **Complete Interim RI Analytical Results**

TABLE

GROUND WATER ANALYTICAL RESULTS - ORGANICS  
Q DRUM STORAGE YARD (SITE 3)

	DETECTION LIMITS			03GW-01			03GW-02			03GW-03			03GW-04		
	01	02	03	01	02	03	01	02	03	01	02	03	01	02	03
VOLATILE ORGANICS															
VINYL CHLORIDE	10	10	10	BDL	24	BDL*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
METHYLENE CHLORIDE	10	10	10	10	BDL	BDL*	26	NDB**	BDL	14	14	BDL	14	NDB**	BDL
1,1-DICHLOROETHANE	10	10	10	115	140	BDL*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TRANS-1,2-DICHLOROETHYLENE	10	10	10	8000	9000	5600*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1,1,1-TRICHLOROETHANE	10	10	10	45	42	BDL*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TRICHLOROETHYLENE	10	10	10	6000	1800	1000*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1,1,2,2-TETRACHLOROETHYLENE	10	10	10	12	19	BDL*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TOLUENE	10	10	10	23	BDL	BDL*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
ACID EXTRACTABLE ORGANICS															
ALL ACID EXTRACTABLE ORGANICS WERE BELOW DETECTION LEVEL															
BASE NEUTRAL EXTRACTABLE ORGANICS															
DI-N-BUTYLPHthalATE	10	10	10	11	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
PYRENE	10	10	10	13	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
BIS(2-ETHYLHEXYL)PHthalATE	10	10	10	130	BDL	BDL	25	25	BDL	18	18	BDL	24	BDL	BDL
PESTICIDES/PCB'S															
ALL PESTICIDES/PCB'S WERE BELOW DETECTION LEVEL															

NOTES: All values for ORGANICS in ug/l.

\* = Sample detection limit is 125 ug/l using a 1:12.5 dilution.

NDB\*\* = Compound was also detected in the blank at a concentration greater than 1/2 the sample concentration and 1/2 the detection limit.

LEGEND: 01 = FIRST ROUND - DEC. 1, 1983  
02 = SECOND ROUND - AUG. 29, 1984  
03 = THIRD ROUND - APR. 14, 1986

TABLE

GROUND WATER ANALYTICAL RESULTS - INORGANICS  
Q DRUM STORAGE YARD (SITE 3)

INORGANICS PRIORITY POLLUTANTS	DETECTION LIMITS			03GW-01			03GW-02			03GW-03			03GW-04		
	01	02	03	01	02	03	01	02	03	01	02	03	01	02	03
ANTIMONY, TOTAL	0.05	0.05	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.30	BDL	BDL
ARSENIC, TOTAL	0.05	0.05	0.05	0.20	BDL	BDL	0.13	BDL	BDL	0.20	BDL	BDL	0.50	BDL	BDL
CADMIUM, TOTAL	0.02	0.01	0.01	0.02	0.01	0.02	0.02	BDL	0.02	0.02	BDL	0.09	BDL	BDL	BDL
CHROMIUM, TOTAL	0.10	0.05	0.05	0.10	0.10	BDL	0.10	0.22	BDL	0.45	0.25	BDL	140.00	0.13	0.08
COPPER, TOTAL	0.10	0.10	0.10	0.10	BDL	BDL	0.10	BDL	BDL	0.10	BDL	BDL	0.10	BDL	BDL
LEAD, TOTAL	0.20	0.05	0.05	0.30	BDL	BDL	0.23	BDL	BDL	0.32	BDL	0.24	BDL	BDL	BDL
MERCURY, TOTAL	0.0002	0.0002	0.0002	BDL	BDL	BDL	0.0007	0.0003	BDL	0.001	BDL	BDL	BDL	BDL	0.00078
NICKEL, TOTAL	0.10	0.10	0.10	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.11
SELENIUM, TOTAL	0.05	0.01	0.01	0.10	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
THALLIUM, TOTAL	0.05	0.05	0.05	0.12	BDL	BDL	BDL	BDL	BDL	0.06	BDL	BDL	0.15	BDL	BDL
ZINC, TOTAL	0.02	0.02	0.02	0.30	0.17	BDL	0.30	0.13	0.04	0.40	0.13	BDL	0.30	0.05	0.16
PHENOLS	0.01	0.01	0.01	BDL	0.10		BDL	BDL		BDL	BDL		0.01	BDL	

NOTES: All values for INORGANICS in mg/l.

LEGEND: 01 = FIRST ROUND - DEC. 1, 1983  
02 = SECOND ROUND - AUG. 29, 1984  
03 = THIRD ROUND - APR. 14, 1986

TABLE 6-5

GROUND WATER ANALYTICAL RESULTS - SPECIAL ANALYSIS  
Q DRUM STORAGE YARD (SITE 3)

SPECIAL ANALYSIS	DETECTION LIMITS				03GW-01				03GW-02			
	01	02	03	04	01	02	03	04	01	02	03	04
OIL AND GREASE (mg/l)	0.05	2.00	2.00		80	BDL	BDL		74	BDL	BDL	
m-XYLENE			10.00	5.0			BDL*	BDL			BDL	BDL
o,p-XYLENE			10.00	5.0			BDL*	BDL			BDL	BDL
METHYLETHYLKETONE			10.00	10.00			BDL*	BDL			BDL	BDL
METHYLISOBUTYLKETONE			10.00	10.00			BDL*	BDL			BDL	BDL
1,2-DIBROMOETHANE			0.015	0.015			BDL	BDL			BDL	BDL
1,2-DIBROMO-3-CHLOROPROPANE				0.015				BDL				BDL

SPECIAL ANALYSIS	DETECTION LIMITS				03GW-03				03GW-04			
	01	02	03	04	01	02	03	04	01	02	03	04
OIL AND GREASE (mg/l)	0.05	2.00	2.00		40	BDL	BDL		110	7	610	
m-XYLENE			10.00	5.0			BDL	BDL			BDL	BDL
o,p-XYLENE			10.00	5.0			BDL	BDL			BDL	BDL
METHYLETHYLKETONE			10.00	10.00			BDL	BDL			BDL	BDL
METHYLISOBUTYLKETONE			10.00	10.00			BDL	BDL			BDL	BDL
1,2-DIBROMOETHANE			0.015	0.015			BDL	BDL			BDL	BDL
1,2-DIBROMO-3-CHLOROPROPANE				0.015				BDL				BDL

NOTES: All values for SPECIAL ANALYSIS in ug/l.

\* =Sample detection limit is 125 ug/l using a 1:12.5 dilution.

LEGEND: 01 = FIRST ROUND - DEC. 1, 1983

02 = SECOND ROUND - AUG. 29, 1984

03 = THIRD ROUND - APR. 14, 1986

04 = FOURTH ROUND - JUN. 25, 1986

TABLE 6-6

SOIL ANALYTICAL RESULTS - ORGANICS  
 FIRST ROUND SAMPLING EVENT  
 Q DRUM STORAGE YARD (SITE 3)

		03S-05			03S-06			03S-07			03S-08		
	DETECTION												
VOLATILE ORGANICS	LIMIT	(0-1')	(1-2')	(2-3')	(0-1')	(1-2')	(2-3')	(0-1')	(1-2')	(2-3')	(0-1')	(1-2')	(2-3')
METHYLENE CHLORIDE	10	BDL	BDL	BDL	BDL	BDL	BDL	27	BDL	BDL	12	BDL	BDL
TRANS-1,2-DICHLOROETHYLENE	10	BDL	BDL	BDL	1100	180	16	83	BDL	BDL	BDL	BDL	BDL
1,1,1-TRICHLOROETHANE	10	BDL	BDL	BDL	27	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TRICHLOROETHYLENE	10	BDL	BDL	BDL	7000	3600	1100	BDL	BDL	BDL	BDL	BDL	BDL
ACID EXTRACTABLE ORGANICS													
PHENOL	500	BDL	BDL	BDL	3400	2200	BDL	BDL	BDL	BDL	BDL	BDL	BDL
2,4-DIMETHYLPHENOL	500	BDL	BDL	BDL	720	BDL	BDL	4800	BDL	BDL	BDL	BDL	BDL
BASE-NEUTRAL EXTRACTABLE ORGANICS													
1,4-DICHLOROBENZENE	200	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2000	BDL	BDL
N-NITROSCOT-N-PROPYLAMINE	200	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	10000	BDL	BDL
1,2,4-TRICHLOROBENZENE	200	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2000	BDL	BDL
ACENAPHTHENE	200	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2000	BDL	BDL
2,4-DINITROTOLUENE	200	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1800	BDL	BDL
PHENANTHRENE	200	600	BDL	BDL	BDL	BDL	380	BDL	BDL	BDL	BDL	BDL	BDL
DI-N-BUTYLPHTHALATE	200	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2000	BDL	BDL
FLUORANTHENE	200	700	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
PYRENE	200	520	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1800	BDL	BDL
BENZO(A)ANTHRACENE	200	260	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
CHRYSENE	200	260	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
PESTICIDES/PCB'S													
4,4'-DDT	2.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.1	BDL	BDL	BDL	BDL
4,4'-DDE	2.0	BDL	BDL	BDL	BDL	BDL	BDL	5.4	5.7	BDL	BDL	BDL	BDL
4,4'-DDD	2.0	BDL	BDL	BDL	BDL	BDL	BDL	130	160	3.7	BDL	BDL	BDL
ENDOSULFAM SULFATE	2.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	21	800

ALL RESULTS ARE IN  $\mu\text{g}/\text{kg}$ ; SAMPLES WERE TAKEN IN DECEMBER, 1983



TABLE 6-7

SOIL ANALYTICAL RESULTS - INORGANICS  
FIRST ROUND SAMPLING EVENT  
Q DRUM STORAGE YARD (SITE 3)

INORGANICS PRIORITY POLLUTANTS	DETECTION	03s-05			03s-06			03s-07			03s-08		
	LIMIT	(0-1')	(1-2')	(2-3')	(0-1')	(1-2')	(2-3')	(0-1')	(1-2')	(2-3')	(0-1')	(1-2')	(2-3')
ANTIMONY, TOTAL	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
ARSENIC, TOTAL	0.05	23	BDL	14	21	5.3	8.4	6.5	14	4.7	32	6.2	21
BERYLLIUM, TOTAL	0.02	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
CADMIUM, TOTAL	0.02	2	1.4	1.2	1	0.5	0.6	1.3	0.5	1.3	1	1	1
CHROMIUM, TOTAL	0.10	16.00	10.00	8.00	20.00	9.70	8.40	12	6.4	12	17	16	8.4
COPPER, TOTAL	0.10	5.10	5.60	1.2	5.20	0.50	0.60	4.7	2	1.3	11	1.8	1.9
LEAD, TOTAL	0.20	28.00	34	7.6	23.00	8.30	5.40	32	13	13	21	9.2	7
MERCURY, TOTAL	0.0002	0.08	0.14	0.06	0.03	0.06	0.08	0.11	0.24	0.03	0.03	0.025	0.045
NICKEL, TOTAL	0.10	5.10	3.30	2.4	4.20	1.40	1.20	5.1	1.5	1.7	22	1.8	2.4
SELENIUM, TOTAL	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
SILVER, TOTAL	0.06	BDL	BDL	BDL	1	BDL	0.30	BDL	BDL	BDL	BDL	BDL	BDL
THALLIUM, TOTAL	0.05	22	2	12	16	2.80	2.50	2	6	2	21	9	6.6
ZINC, TOTAL	0.02	53.00	42.00	11.00	28.00	9.70	9.10	30	12	11	30	15	10

Note: All values taken in ug/g.

TABLE 4

SOIL ANALYTICAL RESULTS  
THIRD ROUND SAMPLING EVENT  
Q DRUM STORAGE AREA (SITE 3)

		03S-09			03S-09A			03S-10			03S-11			03S-12			03S-13			03S-14			03S-15		
	DETECTION																								
	LIMIT	(0-1')(1-2')			(0-1')(1-2')(2-3')			(0-1')(1-2')(2-3')			(0-1')(1-2')(2-3')			(0-1')(1-2')(2-3')			(0-1')(1-2')(2-3')			(0-1')(1-2')(2-3')			(0-1')(1-2')(2-3')		
VOLATILE ORGANICS																									
METHYLENE CHLORIDE	10	BDL	BDL	BDL	BDL	BDL	10	BDL	13*	BDL	BDL	BDL	BDL	BDL	BDL	BDL	16	14	15	14	BDL	17			
BASE-NEUTRAL EXTRACTABLES																									
BUTYLBENZYLPHTHALATE	330	BDL	BDL	BDL	BDL	BDL	BDL	BDL	530	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
ACID EXTRACTABLES	ALL BELOW DETECTION LIMIT																								
SPECIAL ANALYSIS																									
METHYLETHYLKETONE	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
METHYLISOBUTYLKETONE	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
m-XYLENE	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
o,p-XYLENE	10	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
OIL & GREASE	25	140	300	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	140	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
E.P. TOXICITY (mg/l)																									
CADMIUM	0.01	BDL	---	---	0.01	---	---	0.01	---	---	0.01	---	---	BDL	---	---	0.01	---	---	0.08	---	---			
CHROMIUM	0.05	BDL	---	---	BDL	---	---	BDL	---	---	BDL	---	---	BDL	---	---	BDL	---	---	BDL	---	---			

NOTES: All concentrations are in mg/kg.

\* = Compound was also detected in the blank at a concentration greater than 1/2 the sample concentration and 1/2 the detection limit.

--- No analysis conducted.

TABLE 6-9

NAVY SOIL ANALYTICAL RESULTS  
 APRIL 28, 1986  
 Q DRUM STORAGE YARD (SITE 3)

PARAMETER	DETECTION LIMIT	SAMPLE LOCATION							
		A	B	C	D	E	F	G	H
Arsenic	5	38	11	5	5	<5	<5	10	12
Barium	20	<20	<20	<20	<20	<20	<20	<20	<20
Cadmium	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	1	4.0	1.8	<1	<1	2.7	2.3	1.5	<1
Lead		15	14	48	42	20	26	34	7
Mercury	0.1	0.17	<0.1	<0.1	0.22	<0.1	<0.1	<0.1	<0.1
Selenium	2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
Silver	1	<1	<1	<1	<1	<1	<1	<1	<1
pH		7.3	7.4	7.6	9.3	8.0	7.7	7.8	8.1
Oil & Grease		6,785	21,300	10,100	18,800	54,100	51,500	30,000	4,120
TOX	100	120	100	190	<100	140	715	135	<100
EP TOX Pb	60	<60	<60	<60	<60	<60	<60	<60	<60

Note: All detection limits in mg/kg except EP TOX Pb which is in ug/l.

FIGURE 6-2 indicates approximate locations of NAVY soil samples.

**APPENDIX B**  
**SITE PHOTOGRAPHS**





**TYPICAL DRUM STORAGE AT QADSY (NOTE SOIL STAINING)**



**DAMAGED DRUM STORAGE AT QADSY**

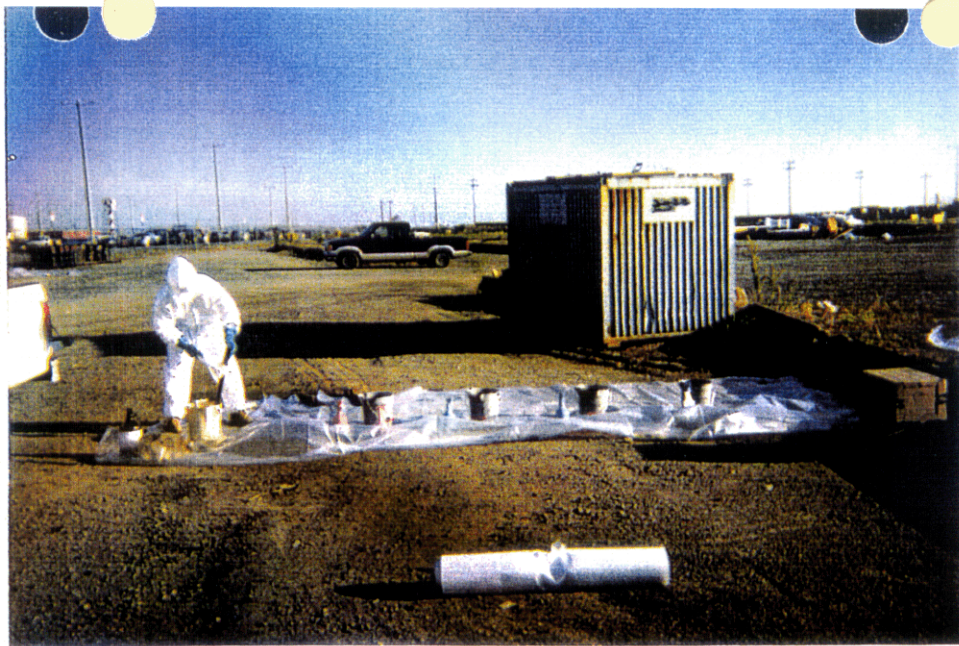


**DRUM STORAGE, CONCRETE FOOTINGS, AND SOIL STAINING**



**DETAIL OF CONCRETE FOOTINGS USED FOR DRUM STORAGE**

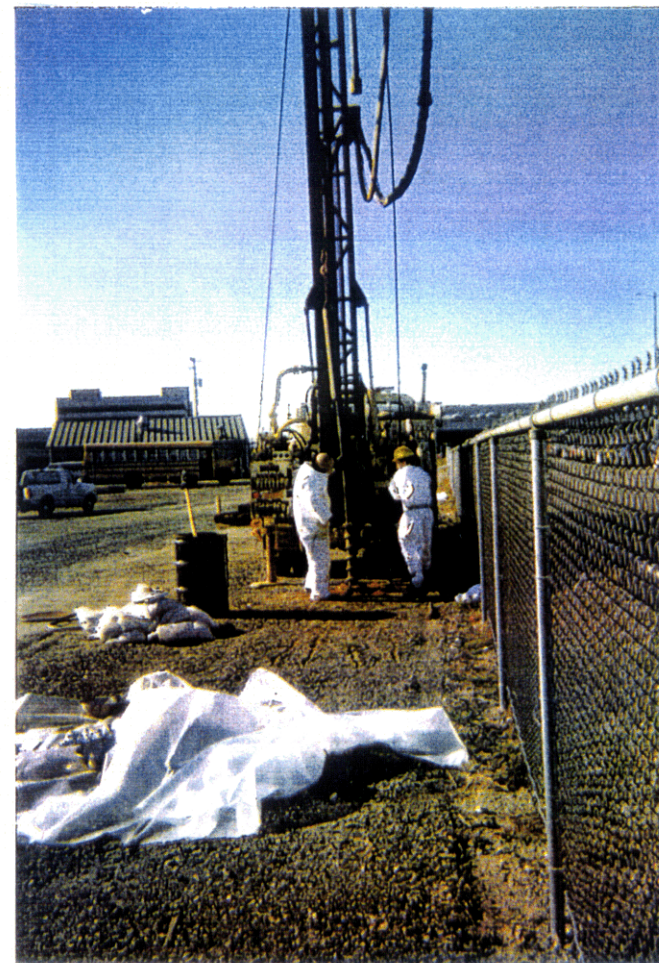




**EQUIPMENT DECONTAMINATION STATION**



**SURFACE SOIL SAMPLING USING HAND AUGERS**



**SOIL BORING PRIOR TO MONITOR WELL INSTALLATION**





**PUMPING WELL, INCLUDING DISCHARGE LINE AND  
PRESSURE TRANSDUCER, DURING PUMP TEST**

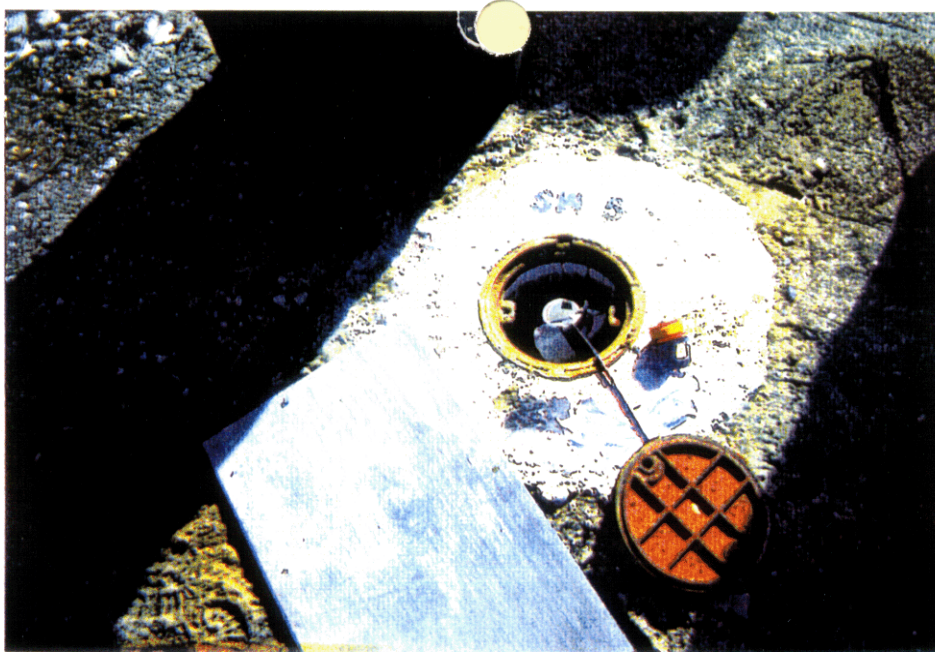


**TANKER TRUCK USED TO CONTAIN DISCHARGE  
WATER DURING PUMP TEST**



**DATA LOGGER USED TO COLLECT PUMP TEST RESULTS**





**PRESSURE TRANSDUCER IN OBSERVATION  
WELL DURING PUMP TEST**



**CONDUIT USED TO PROTECT PRESSURE TRANSDUCER  
CABLE DURING PUMP TEST**



**Appendix C**  
**Field Notebook**

DATE

DATE

10-1

DATE

PAGE

DATE

PAGE

15.45 to 15.55  
Augered PP-1

16.10 to 16.18  
Augered PP-12

17.15 Took soil equip. blank

- Called in AM to have drums  
and isopropanol delivered tomorrow  
should arrive after noon

8.58 to 9.10  
Augered PP-5

9.25 to 9.40  
Augered PP-8

10.20 to 10.37  
Augered PP-10

10.50 to 10.58  
Augered PP-13

13.33 to 13.47  
Augered PP-14  
PP-11-2 KD is actually field  
dup for PP-14-2.

14.21 to 14.50  
Augered PP-4

JOB

DATE

PARTY CHIEF

PAGE

JOB

DATE

10-1

PARTY CHIEF

PAGE

Carol & George completed all but  
two C.P.P. 7 & 8 in the  
petroleum products area.

Reported relatively high readings  
in the hazardous material area  
however we believe the volatiles  
are dissipating in the air rapidly  
therefore we will have H.T.  
retreat samples in two <sup>11m</sup> areas  
with a 3" split spoon. From  
there we will collect the sample  
directly from the spoon <sup>and put it</sup> into the  
400 ml bottles.

Carol & Ken discussed surveying  
the wells on site, we will not  
have to do this ourselves (ESS)  
- Ken will issue charge order  
to have G. Area 1 CD landfill  
surveyed (professionally). will  
also cover sampling of existing  
wells.

DATE

PAGE

10:08 to 10:30

Augered PP-7

10:39 to 11:11

Augered PP-9

14:10 to 14:53

Augered EX-1

15:15 to 15:33

Augered EX-2

16:05 to 16:15

Augered EX-3

## EARLY AFTERNOON

- Ran water cover by site

- tested about higher pumping rate on pumping test

- how hard it affect deeper aquifer

- plans to run physical parameters on soil for groundwater modeling

JOB

DATE

JOB

G' AREA

DATE

10-2-90

PARTY CHIEF

PAGE

PARTY CHIEF

Bence/Shawby/Borg/11/11

Arrived on site @ 08.30 AM  
had a first look

V.V.I. had to have materials  
(1" under pipe) delivered from  
Baltimore M.D. There might have  
been a misunderstanding as  
the depth of Dwell. 1111  
thought it was 25 feet. Re-  
ch to 45 feet (10' screen, 35'  
casing)

Completed Sur. to 25 feet  
Began Dwell

Some contamination  
from C. 1111 and AS to 25'  
+ found a few thin lenses  
of clay (not confining)

1111 did not have enough  
under pipe for the G' well  
More material will arrive  
10-3-90 pulled 4" augers out

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

JOB ..... DATE 10-3

PARTY CHIEF ..... PAGE .....

0700 Arrived on site

- called back about getting water pump

will arrive tomorrow AM

9:00 Picked up hydrogen tank  
for CVA

Collected a third soil sample from  
Hole 3; ~~still get~~ the drill bit  
Same morning 12 10:20

W42 are completing the mobile usage  
until the 6th self contained drive

JOB

DATE

JOB

DATE 10-2

PARTY CHIEF

PAGE

PARTY CHIEF

PAGE

10:30 - called Fine. It looks as if  
DEUMS should arrive in AM

Received 4" pump from KSC -  
Dylton instead of 2" pump  
requested.

- called around to find hydrogen

10:35

~~2005~~ Took soil equip blank

Completed 2 soil borings w/ 16" rig  
HM 54, HM 9 Utilized a 3" <sup>1/2</sup>  
spoon. Purpose of these two borings  
was to collect the soil quickly into  
the 60 Abo<sup>11</sup> before they evaporate into  
the atmosphere.

# of Drains

1  
1  
3

1  
1  
1

7

4

8:26  
8:40  
9:20  
8:25  
8:15  
9:09  
8:50  
9:02  
8:35  
~~8:40~~  
9:00

ROP  
DATE TIME *Shelby George*

10-5

Ansite		C 7.00	
		Before Developing	
Liquid Level		New began @ 0815	
Heat Space	Well #	DTU	TD
1000 +	SW-1	7.21'	22.45
990	SW-2	7.68'	21.33
0	SW-3	8.48'	23.32
300	SW-4	7.40'	24.25
0	SW-5	5.83'	25.54
0	SW-6	7.73'	21.47
0	SW-7	6.19'	23.14
1000 +	SW-8	7.84'	23.26
0	DW-1	8.23'	43.75
<del>990</del>	<del>DW-2</del>	<del>8.23'</del>	<del>44.25</del>
0	DW-2	8.51'	42.46



DATE

DATE

DATE

104

DATE

DATE

DATE

DATE

7:30 ON SITE

10-8-90

SW-3

PAGE

Began developing @ 13:15  
H<sub>2</sub>O was cloudy (gray in color)  
H<sub>2</sub>O fairly clear around 14:35  
developing stopped @ 14:55

10-9-90

SW-1

Began developing @ 0815  
H<sub>2</sub>O was very cloudy  
H<sub>2</sub>O was developing completed  
@ 1009 200 ppm

10-9-90

Began developing SW-2 @ 1015  
H<sub>2</sub>O very cloudy (grayish in color)  
developing stopped @ 1057  
OVA over 1000 ppm

10-9-90

SW-1 OVA reading @ 900 ppm

Began developing around @ 1223  
H<sub>2</sub>O dark gray in color  
H<sub>2</sub>O clear at end  
developing stopped @ 1355

PAGE

SW-6

10-9-90

OVA reading 1 ppm  
SW-6 Began developing @ 1436  
H<sub>2</sub>O very muddy, dark grayish  
in color  
developed stopped @ 1630

10-9-90

SW-2

OVA reading 900 ppm  
Began developing @ 1702  
H<sub>2</sub>O cloudy  
Stopped developing @ 1740  
H<sub>2</sub>O clear

10-9-90

OVA reading 0 ppm  
Began developing @ 1757 (SW-6)  
H<sub>2</sub>O orange & brown in color  
Stopped development @ 1915

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

Began developing SW 5 @ 12:40  
- water very dirty (dark gray)  
- water fairly clean @ 13:15  
- See well sampling data form

Began developing SW 4 @ 14:05  
- water v. dirty (almost black)  
- water fairly clean @ 15:30  
See well data form

10/8/90

Began developing SW 8 @ 18:10  
- water v. dirty  
- 1 1/2 fairly clean @ 19:45  
- See well sampling data form  
Water level after developing  
6.27

Stopped, put off tubing

DATE 10/19  
 JOB  
 PAGE  
 GAU SW-3  
 Sampling BW # 3 Start 1140 End 1353

Boring 12" Well Case 6"

DTW 8.64

Column of H<sub>2</sub>O in Well  
 Casing Length 23.34  
 DTW 8.64  
 Column of H<sub>2</sub>O 14.7

Volume to be Removed  
 A.S. From Chart 1.32  
 Column of H<sub>2</sub>O 14.70  
 Vol. A. Space 19.40  
 gal/ft of Case 1.4689  
 Column of H<sub>2</sub>O 14.7  
~~Total Vol of Case~~ 21.59  
~~Total vol evacuated~~ 40.99  
 # ~~Total~~ vol evacuated 3  
 Total vol. ev 122.97

# Field Analyses

	Start	Mid	End
Time	1152	1226	1315
pH	7.25	7.59	7.49
Cond	-16	-3	-27
Temp	22.4	23.9	23.8

JOB

DATE

PARTY CHIEF

SW-5

PAGE

Sampling

SW-5 • Started purging at  
0830 for sampling  
• H<sub>2</sub>O clear  
• End of purging @ 0915

Time of sampling: 1310 for 15'  
1338 for 25'

Samples for 5-2 were  
cloudy

Field Blanks 1425  
Finished blanks @ 1438

JOB

DATE

PARTY CHIEF

SW-4

PAGE

Sampling

SW-4 • Started purging @ 0930  
• H<sub>2</sub>O cloudy  
End of purging @ 1020

Time of sampling: 1448 for 15'  
1457 " 25'

DATE 10/16  
 SW-6  
 Skrt 0926  
 End 1011

D7W 7.59  
 Casing length 2500  
 D7W 7.59  
 Volume H<sub>2</sub>O 17.41

Volume to be removed

gal/H of NS 73  
 Volume of H<sub>2</sub>O 17.41  
 Volume of Annular Space 12.71  
 gal/H of Casing 14.32  
 Volume of H<sub>2</sub>O 17.41  
 Volume of Casing 28.4  
 Total volume 15.55  
 Number of volume removed 3  
 Total number evacuated 46.69

10/17

10/16  
 Field 1 min. 1/50 3  
 Time 0.153 0.153  
 pH 7.10 7.33  
 Temp 21.3 21.1  
 Temp 21.9 21.8

10/17  
 Field Analysis

SiVA 1 ppm

Unit had to stop work pump broke down

JOB

DATE

PARTY CHIEF

SW-7

PAGE

Start 0814		End 0715	
DW 623			
Casing length	2500'		
DW	623		
Column of H <sub>2</sub> O	1877		
Volume to be removed			
gal/ft of AS		273	
Column of H <sub>2</sub> O		1877	
Volume of Annular Space		1378	
gal/ft of Casing		1632	
Column of H <sub>2</sub> O		1877	
Volume of Casing		306	
Total Volume		1676	
Number of volume evacuated		3	
Total volume evacuated		5028	

JOB

DATE

PARTY CHIEF

PAGE

Start 0814		End 0715	
DW 623			
Casing length	2500'		
DW	623		
Column of H <sub>2</sub> O	1877		
Volume to be removed			
gal/ft of AS		273	
Column of H <sub>2</sub> O		1877	
Volume of Annular Space		1378	
gal/ft of Casing		1632	
Column of H <sub>2</sub> O		1877	
Volume of Casing		306	
Total Volume		1676	
Number of volume evacuated		3	
Total volume evacuated		5028	

Shirley / Bodfrey

Arrived in P. 10-28

@ 9:30 p.m.

Sunny & cool 3-55°

At 11:00 10-29

Todd & I received our base passes

Wrote to Mr. Hooker about opening & closing the gate in O Area from 7 AM to 5:30 p.m. Will do so next up to Wednesday 10-31-80 unless otherwise informed or changes

Repaired OVA suction line, it was clogged



JOB

DATE

JOB

DATE

PARTY CHIEF

PAGE

PARTY CHIEF

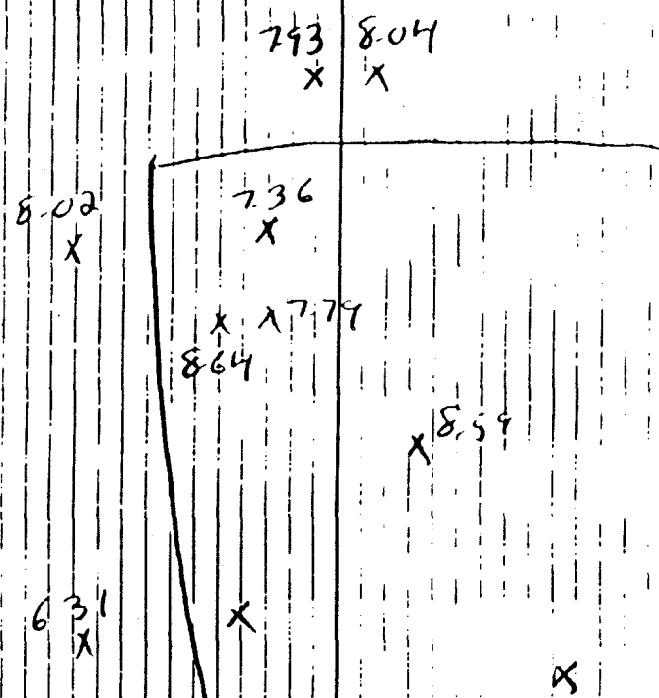
PAGE

17 Oct 1990  
Well Levels

WELL	DTW	OVA	DTB	
SW-5	5.95	0	25.90	- felt bottom
SW-4	7.38	1000+	24.32	- under pressure - out pealed at 10m then road 0
SW-7	6.23	0	24.37	- bottom firm - not hard
SW-6	7.64	0	23.84	- felt bottom
SW-8	8.01	1000+	24.73	- rock hard bottom
DW-2	8.11	0	42.21	- rock hard bottom
SW-3	8.65	0.5	23.31	- rock hard bottom
DW-1	7.89	5	43.76	- felt bottom hard
SW-2	7.83	1000+	24.86	- under pressure - H <sub>2</sub> O ↑ rock hard bottom coming up - started at 8.19
SW-1	7.42	1000+	23.90	

26 Oct 1990

Last Week's Levels (Wed Oct 10)



DW-1 WT - 5.00 feet

13.00

Began purging well  
@ 14.47 fairly clean

0 volatile organic  
well was not under pressure

Included wellbore logs in  
the three samples mentioned  
above (SW-2 has two samples)  
Placed evidence tape on  
coker before Fed Ex

WT before sampling 5.04  
sample was dirty (gritty)

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

11.45 ~~to~~ began purging well 1542  
well under pressure  
CVA reading 999 ft  
after a few seconds  
there was no volatile  
reading

SW - 2 water table - 7.82

Blow a fuse to pump,  
did not start & purging  
till 12.45

12.45 7.32  
Bgm Temp 20.9  
C - 20

water was initially very cloudy,  
in a few minutes it cleared  
up (see well sampling data  
form). Very fine fragments in water.

water table when  
sampling was  
7.82 feet

11.45 to 12.45

SW-8

meas. began @ 0945

QVA = 999 +

WT = 7.96 FT

Time	10:05	10:21	10:46
pH	7.88	7.85	7.88
Cond	-52	-50	51
Temp	22.7	22.8	21.0

Began purging well @ 0955

water is very dirty (muddy)

Purged 51 gallons

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

JOB .....

DATE 10-30-90

PARTY CHIEF

Shelley / Caffrey

Clear but cool  $\pm 1.5^{\circ}$

Arrived on site @ 0700  
Gate was not opened until 0715

08:00 Began measuring the volatile  
w/ WT on DCU-2

OV'A reading = 2.8 ppm  
WT = 18.00 per

Purging began @ 0821  
in the very dirty

SEP-6

begin measuring @ 16.10

CWA reading 0

WT 760

Begin fusing @ 16.13

water clarity (gently)

Time	16.15	16.35
pH	7.58	7.58
Cond	- 33	- 34
temp.	21.0	20.4

END fusing @ 17.05

JOB

DATE

JOB

DATE

PARTY CHIEF

PAGE

PARTY CHIEF

PAGE

Sewer

Measurements began @ 13:00

DVA Reading 99918

WT 7.38'

(water initially &amp; daily (youth))

Time	13:35	13:35	13:51
WT	7.18	7.41	7.51
Cond	-11	-24	-30
Temp	22.4	23.1	22.2

Surgery began @ 13:10

water table before sampling  
7.45'

Retrieved FD from Sewer  
@ 25 feet from 17:30 to 18:05  
Bottle of displaced water  
Sewer FD

finger regulations

10-31-90

## Skidley / Godfrey

Arrived @ 8:05

Decom. the pump to begin  
developing the existing  
four monitoring wells located  
in the paved parking lot.

08:00 began developing exist. well  
W-1A WT 8.80 ft  
1 foot 3 1/2" of mud TD 12.24.9 ft

Sediment on bottom  
1. 2 ft. of M. dirty (heavy  
orange sediment in water)  
clean up just well

Pumping ended @ 09:05  
Pumped 55 gallons

No cotton plug in well



NO.

DATE

NO.

NO.

ENTER CASE

PAGE

ENTER CASE

PAGE

Parties & delivered all  
samples to Federal Express  
evidence tape was placed on  
the cooler

904  
776  
337  
774  
3318  
3877  
5210

MU-1C

C940

water table 8.47

T D 2530

water table bottom

water, size 3"

water very dirty (dark  
brown)

has a strong odor once  
it began developing  
smells like sewage  
sawyer gas. Either it  
smells like shit!

water cleared up very  
quick (10 minutes)

No dollar plug

Began paying @ C945  
charged 42 gallons  
End 10:20

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

MCU-B

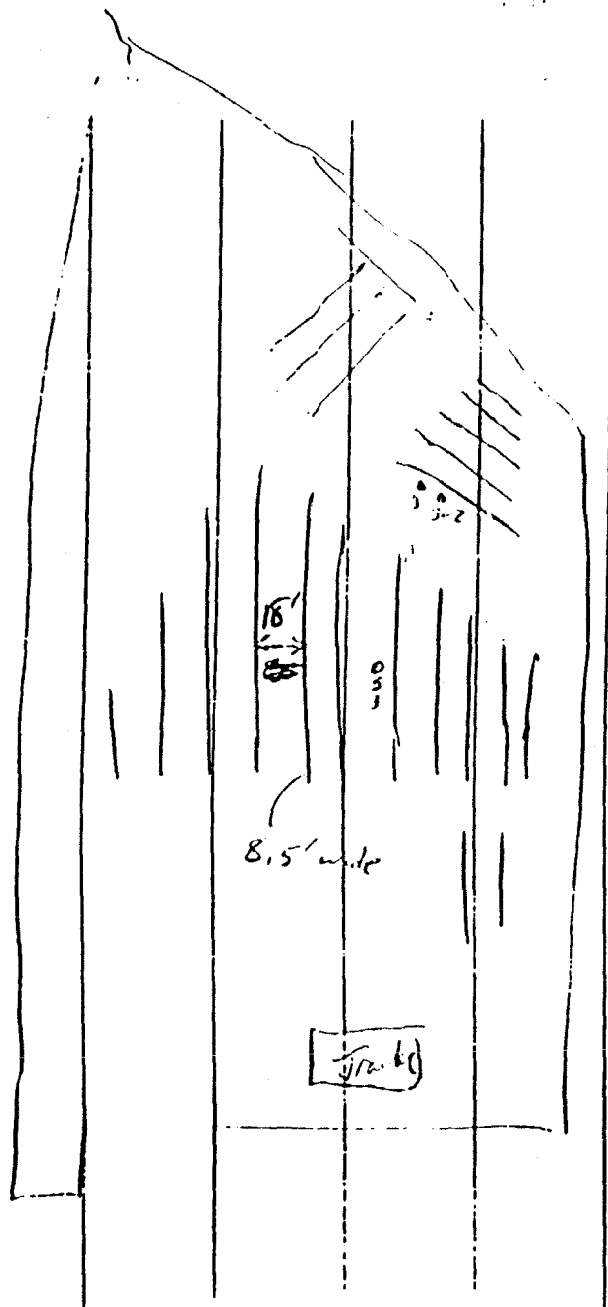
WT - 9.49

TD - 26.82

Sediment in bottom  
rises pipe = 1' 1"

COULD NOT DEVELOP THIS  
WELL. COULD NOT LOWER  
THE PUMP OR BAILEY BELOW  
16 FEET

No dollar plug.



Began with  
 X SW-3  
 PVC 5.07 5.08  
 Topo 49.01 4.92

X SW-3 to SW-2 213'  
 PVC 5.90  
 T = 5.64  
~~N 29 W~~  
~~5.29 E~~

X SW-3 to DW-1  
 PVC 5.78  
 T = 5.65  
~~N 33 W~~  
~~5.37 E~~

X SW-3 to SW-1  
 PVC 6.35  
 T = 5.91  
~~N 16 W~~  
~~5.16 E~~

X Rod off

JOB ..... DATE .....

JOB ..... DATE .....

ENTRY CHIEF ..... PAGE .....

ENTRY CHIEF ..... PAGE .....

MWD measured @ 1040  
WT 9.40  
TD 2470 w/ little sediment  
inner pipe 1' 2 1/2"  
collar broken  
No collar plug

Began purging @ 1046  
water was dirty (yellow)  
orange brown in color  
Started to clear up ~ 5 minutes

From AT A to SW-6  
PVC 4.99  
Topo 4.56  
N 15 E

From <sup>B</sup>at <sup>new</sup> MW A to SW-6  
PVC 5.20  
Topo 4.80  
S 9 W

From Pt B to MW A  
PVC 3.94  
Topo 5.37  
S 6 W

From Pt B to MW B  
PVC 3.43  
Topo 4.45  
N 10 W

JOB

DATE

JOB

DATE

PARTY CHIEF

Distance

PAGE

PARTY CHIEF

PAGE

From	To	
SW2	Dw1	10.5'
SW3	SW2	213'
SW5	SW3	322'
SW3	SW7	273'

SW3 to SW5

PVC 7.87

Topo 7.80

~~N 31 W~~

S 31 E

SW3 to SW4

PVC 6.45

Topo 6.28

S 31 W

A between SW6 &amp; SW7

From DT A to SW4

PVC 5.27

Topo 5.10

N 78 E

From pt A to SW7

PVC 6.50

Topo 5.97

S 20 W

From <sup>mw.</sup> ~~C~~ C To MWD  
 PVC 4.22  
 Top 5.57  
~~18~~ 540 E

# IX Triangulation

From	To	Bearing
mw C	DW 2	N80E
YH	SW-8	N82E
SW-8	mw-D	S18 E
DW 2	mw-D	S12 E
mw C	mw B	N46W
mw B	mw A.	S01 E
SW 4	SW-7	S46W
SW 3	SW-6	S71W
DW 1	mw A	N64W
DW 1	SW 1	N43E
DW 1	SW-2	S50 E
SW-2	SW-3	S12 E



JOB ..... DATE .....

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

PARTY CHIEF ..... PAGE .....

From Pt C to MW-B  
PVC ~~5.14~~ 4.10  
Topo 5.14  
N 67 W

From Pt C to MW-C  
PVC 4.99  
Topo 5.23  
S 49 E

From Pt C to DW-2  
PVC 5.33  
Topo 5.11  
S 80 E

From Pt C to SW-8  
PVC 5.41  
Topo 5.11  
S 78 E

JOB

DATE

JOB

Q Area

1/28/91

EARTH CHIEF

PAGE

EARTH CHIEF

Skabacz / Gale / Chappin weather clear  
50-55

1/28/91 MC

Received a new day pass @ 0630  
 Papers from K. Walker did not  
 arrive @ pass office then  
 will have all the paper work  
 @ the pass office @ the end of the  
 day.

1040 Repair pump - GW-1 @ 1040  
 Parged 50-55 gallons before  
 pumping

Picked up (3) 55 gallon  
 drums @ Fire Lbr Co.  
 for parging

Began sampling GW-1(K) @ 1120

1140 Decon bailer w/ trailer

1220 Sample GW-1(K), w/ extra  
 bottle for retails + decon bailer

1350 - Parge 50 gals from GW-3,  
 north of Q Area.

1430 Sample GW-3U, decon bailer  
 Lay out lines + set probes for Pump

JOB Q-444

DATE 1-16-51

PARTY CHIEF Forrest Martin

PAGE 1 of 2

7.45 Left Bristol for Fife  
 Saturday to get skins  
 & 15 bottles, brooms (3)  
 8.45 We arrived at 2.00  
 we met with Mrs. King  
 from Norfolk

715 Bacon Ridge, Colorado, pH

9:45 Puyugan ~~At~~ C.V-1 10-7/6 TO

10 30	Finish Pumping	1000
	500 (1000)	

10.30	Recor	Temp
-------	-------	------

10.45 Bryan, ECU 4 100-94472

11:30	Finish Pumping	6:45 - 7
-------	----------------	----------

11:45	Dixon	Reino
-------	-------	-------

12:00	Purgatory	400	3	110	0.32	100
-------	-----------	-----	---	-----	------	-----

12:30 Finish Revising 64-3

12 55	1-24	Sample	B <sup>2</sup> H <sub>4</sub> S	1	Green
-------	------	--------	---------------------------------	---	-------

2. During problems getting inside base. Gate 3 and Gate 4 did not receive any passes. We drove to get passes. I called Vera Young to verify to the pass office who we were.

JOB Q-Aves

DATE 6-18-91

PARTY CHIEF Fernest/Martin

PAGE 2 of 2

14 Oct 1952

Der Saugdruck beträgt

22. 2 1 4 2 1 4

14. 6. 2014 Nikan Brikon

1530 Sample Truck

1515 Sample Equilibrium

7:53:30 Pico B.A. 6-

1550 Sample 6-60-3 C.C.

1645 Deacon B. H.

16 30 Sample for brick + p + c : 4

1740 Picking up Tombs and

Sample for 400 cc. container

1754444 13.5

17	45	4.16.15	4.2.8.15	1.4.15
----	----	---------	----------	--------

Recd. Feb. 21 1911

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466
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Los Angeles # CRL-7 276

JOB

QA

DATE

1/29

PARTY CHIEF

WATER READINGS

PAGE

	Time	DTW	
SW-1	<del>1214</del> 1215	<del>8.66'</del> 7.41'	
SW-2	1210	7.85'	
SW-3	1205	8.66'	
SW-4	1221	7.50'	
SW-5	1219	6.02'	
SW-6	1235	7.90'	
SW-7	—	—	
SW-8	1228	7.96'	
SW-1	1523	7.44'	
SW-2	1520	7.88'	
SW-3	1519	20.00'	
SW-4	1532	7.64'	
SW-5	1528	6.13'	
SW-6	1535	8.09'	
—	—	—	
SW-8	1540	8.00'	

SW-3 Probe depth  
21.68

JOB

DATE

1/29/41

PARTY CHIEF

PAGE

Initial flow meter reading

Turn logger off @ 1250 (N=1)

1330 Test for flow by pumping, stable @ ~ 6 gpm.

1500 Began pump test @ 15.00

@ 6 gpm

1630 Data Logger 1 may not  
keep recording up to 10 min

1710 Abort Test

Once again, stable at ~ 6 gpm

@ 2.5 gpm  
Flow meter reading @ 1000  
gallons, Frank Bule stayed outside  
from 20.00 hours to 04.00 hrs (1-30)1415 Ken notified EEE that the treatment  
centers will not take the g.w. unless  
PCE was analyzed for every tanker.  
Jennings laboratory will analyze samples  
for 1,00.00 on a 24 hour turnaround.

JOB Q-AREA SAMPLING/P-TEST DATE 1/28/91

PARTY CHIEF SKROBACZ/CHAPPE/GALE PAGE

- Test. Start Purging GW-4, 50 galls.
- 1535 - Sample GW-3L including extra bottle for
- 1645 - metals. Decon boiler. Start 18hr tidal monitor
- 1710 - Sample GW-4U. Decon boiler. Starting to get dark
- 1735 - Sample GW-4L, inc metals Collect Field dupe but put a 1220 time on it. Ret to trailer. Decon boiler.
- 1800 Make up field blank
- 1825 Make up equipment rinseate blank
- 1830 Pack samples. Realise insufficient vols collected for dupe, for fingerprints. 2 not 4 collected (1 lite brown ambers).
- 1900 Load coolers, drive to Federal Express + Ship. Cooler sealed + COC taped Airbill #

1/28/91 NC

1/29/90 NC

JOB Q-AREA PUMP TEST

DATE 1/29/91

PARTY CHIEF SKROBACZ/CHAPPE/GALE PAGE 50-55

0700 Received base passes waited until monitoring (tidal) ended  
 1230 Turned logger off  
 Adjusted gate valve on flood meter to indicate pump test. (55-60 gpm)  
 1500 Entered all pertinent data into log  
 Pump test began logging began at the same time

1510 Noted that logger #1 which is connected to pumping well did not record the 1st 10 mins of pumping  
 Called Beck and they replaced software package was shipped 4 CD in behind ~~and~~ the actual logging. Beck recommended to wait a while to see if software package will catch up. It did not!  
 Informed Carol B. of this and that the tanks which the groundwater will be placed in ~~will~~ are dirty (hydrocarbons)  
 Informed tank lines that as tanks must be cleaned before entering Q Area.

# Q-AREA PUMP TEST

DATE 1/30/91

PAULY CHIEF SKROBACZ/CHAPPLE PAGE

	Time	DTW	Time	DTW
SW-1	0835	7.43	1146	7.42
SW-2	0832	7.88	1144	7.89
SW-3	0830	17.41	1140	18.22
SW-4	0842	7.43	1154	7.42
SW-5	0840	5.99	1151	5.98
SW-6	0847	7.71	1157	7.77
SW-7	-	-	-	-
SW-8	0852	7.96	1200	7.96

to be in here.  
0945 Take VOA samples for 2nd tanker truck. Mark will deliver VOAs (for PCB analysis) from 1st and second trucks for quick turnaround prior to disposal of water.

1015 SW-3 Elevation steady @ 17.8' BTOC since 0810.

1120 5830 galls in first tanker - start to fill second tanker. 4700 galls (by the flowmeter) pumped so far. Third tanker at site now as well. We have capacity !!. Too bad we can't pump harder.

1/30/91

PAULY CHIEF SKROBACZ/CHAPPLE

Average flow (and it's been pretty consistent) is 5.22 gpm.  
1140 Check water levels in all wells  
1205 Mark S. at site has delivered VOA samples to Lab. Data tomorrow morning.  
1300 Began to rain (lightly)  
1330 4th tanker arrived on site  
1500 Checked data loggers & battery charge  
Data logger 1 is okay, voltage 11.8 volts  
Data logger 2 is okay, voltage 8.3 not okay, will take water level measurements & then off to a hardware store to purchase battery & cables to charge battery #2

JOB Q-AREA

DATE

PARTY CHIEF

Water Level

PAGE

	T	Elev
SW-1	20:14	7.43
SW-2	20:05	7.89
SW-3	19:46	8.65
SW-4	20:09	7.48
SW-5	20:11	6.03
SW-6	20:15	7.79
SW-7		
SW-8	20:17	7.96

1/29/91

## Water Levels

1/30/91

SW-1	0438	7.45
SW-2	0435	7.90
SW-3	0433	16.8
SW-4	0449	7.63
SW-5	0445	6.15
SW-6	0454	8.03
SW-7		
SW-8	0500	8.00

JOB Q-AREA Pump Test

DATE 1/30/91

weather cloudy

PARTY CHIEF

SKELBACZ/CHAPPLE

PAGE

40-50°

0415 Arrive @ site. Water level  
in SW-3 (Pump well) 16.8'  
Appears steady.

Check water levels in other wells.

0510 Flowmeter reading @ 3870 gals  
started @ 1030 = 2840 gals.  
Test running for 550 minutes  
= Ave 5.16 gpm if flowmeter is  
accurate.

Level in tank truck 42-38 feet

0550 Water level in SW-3 @ 16.5' Level  
Pump water down @ SW-3/4 with  
non-reg. valve sticks.

0615 Make minute adjustment to flow  
gate to maintain drawdown - which  
was creeping up slowly, flow not  
noticeably different on flow meter.

0740 Level in SW-3 17.5'

0810 Level in SW-3 17.6' - stable

0815 Check water levels in wells.

0930 Two large trucks enter Q Area -  
Send them out to parking lot  
until further notice. Not supplied

JOB

DATE

JOB

1-30

EARLY CHPT

PAGE

PARTY CHPT

Shofar (Chapple)

what happened. He ~~didn't~~ <sup>couldn't</sup> tell <sup>no</sup> ~~what~~ what went wrong, however he instructed me to by-pass the battery all together & connect the deep cell w/ the two Keck terminals. I did so. The logger came back on but display the beginning of setting up the logging sequence. However Jack ~~explained~~ <sup>explained</sup> to me that the data over the last two days will still be in the logging and that I should setup the segments according to the data logger #1. I did this. Logger #2 began logging on 20:00 hours 1:30 with seg 1 @ 0028/0240. This segment is 2 readings ahead of logger #1 which at the time of 20:00 hours was 0030/158.



JOB

DATE

1-30-90

PARTY CHIEF

PAGE

	Time	DTW	Time	DTW
SW-1	15:30	7.46	20:29	7.46
SW-2	15:28	7.82	20:27	7.91
SW-3	15:25	19.83	20:24	17.55
SW-4	15:34	7.62	20:34	7.50
SW-5	15:33	6.13	20:31	6.04
SW-6	15:32	8.06	20:39	7.81
SW-7	-	-	-	-
SW-8	15:40	7.99	20:42	7.96

SW-1	23:29	7.44
SW-2	23:37	7.93
SW-3	23:35	18.71
SW-4	23:47	7.45
SW-5	23:43	6.00
SW-6	23:52	7.80
SW-7	-	-
SW-8	23:54	7.96

923000  
534

JOB

DATE

- 30

PARTY CHIEF

PAGE

Thompson / Chapple

02:40

16:00

Battery #2 has 7.02 volts  
Purchased a third battery  
and a battery charger

18:15

Began charging deep cell  
battery & place new battery  
w/ logger. Logger reads  
8.5 volts

19:00

Battery charge is 8.00 volts;  
confused!!!

19:45

Contact Lars Lentz @  
home in ME. He informed  
me to take the panel  
off their battery & disconnect  
one of the two terminals w/  
the external battery still  
connected to the panel.  
I Did! But when doing  
so the damn logger went  
blank. Now I'm pissed!

19:25

Contact Lars once  
again and inform him

## Q-AREA PUMP-TEST

DATE 1/21/91

TIME SKROBACZ/CHAPPE

PAGE Strong SW Wind  
50-55  
occ. lgt rain

1/31/91

MC

- 0015 Pick up gas mob to site. Level in SW-3 17.7'. Generator #2 fine. (Has to be returned by 3 pm 2/1/90)  
Conditions very windy<sup>(SW)</sup> but no rain. 54°F.  
Mark S explained Tigger situation. Will try to check on it + keep it working!!!
- 0045 Have pumped 10000 galls total since we started pumping: 8970 galls on pump test proper. Total time so far 1725 minutes. Flow = 5.2 gpm.
- 0230 Water level in SW-3 @ 17.9'. Steady for last 1 hour or more. Both dataloggers working OK apparently.
- 0320 While checking water level in SW-6. Probe was dislodged slightly from its original position. Put probe back as close as could be to original, based on rust marks on cable from well cover resting on it. Added more duct tape. Naturally, it chose this exact 5 minutes to precipitate torrentially. Will check again later and reaffix if necessary.

## Q-AREA PUMP-TEST

1/31/91

TIME SKROBACZ/CHAPPE

Well	Time	DTW	TIME	DTW
SW-1	0305	7.47	0632	7.48
SW-2	0303	7.94	0630	7.95
SW-3	0300	17.75	0625	17.95
SW-4	0314	7.62	0641	7.63
SW-5	0310	6.12	0639	6.13
SW-6	0320	8.07	0647	7.97
SW-7	-	-	-	-
SW-8	0330	8.00	0652	8.01
Well	TIME	DTW	TIME	DTW
SW-1	0938	7.46	1133	7.46
SW-2	0936	7.94	1132	7.93
SW-3	0935	17.88	1130	17.51
SW-4	0945	7.43	1136	7.42
SW-5	0941	6.00	1134	5.99
SW-6	0950	7.78	1139	7.73
SW-7	-	-	-	-
SW-8	0954	7.98	1141	7.96

JOB ..... DATE .....

PARTY CHIEF ..... PAGE .....

Jennings Lab (Jeff)  
804 425 1498

PARTY CHIEF ..... PAGE .....

23/7 Turn generator ① off  
after eggs are taken.  
Start the pump immediately  
to generator ②  
Checked oil level in ①  
Pump is now running in generator  
② Pick up the notes  
1/30/41 MC

Linda Billingsley 464 9349  
Jennings Lab 425 1498

1030 Cherry/Barrett stopped by to see how things were going. Told me that a change of command aboard the Carrier docked, & sometime tomorrow. This will add significantly to our traffic problems on conduits to SW-6 and SW-8.

1045 Carol Bowers called. Has sent info to Ken Walker. Ken should send to disposal facility at MDEP.

1100 Level in SW-3 17.3'

1130 Check all levels (see table back 2 pages)  
Drive to Hotel to meet MES. Deliver sample to Jennings Lab, and perhaps sleep.

1220 Mark takes samples to Lab. MC stays at site. Yippee!

1222 Total gallons ops pump test 12,570.  
(includes 1030 gal subtracted from)

1230 Switch back to generator #1.  
Ken Walker stopped by. Suggested we get last truck in. Difficulty in getting window at treatment facility. Perhaps tonight in

early hours or evening could be arranged. We need to notify Linda (Franklines) to bring last truck and maybe have standby driver for tonight if it pans out. Also Ken suggested planks to protect SW-6 conduit + cable. Said he will call fleet parking to see if cones can be put up to protect conduit, but doesn't hold out too much hope!! Has sent info on samples to center and is trying to get road from Meryl Wilcoff, if a spec opens up. Treatment facility very busy!!

1245 Switch of generators has sent level in SW-3 to 18.75'.  
Get bored and repair Navy generator so that its wheels are straight and it can be pulled along easily instead of being manhandled - it's the best we could do.

1315 Check dataloggers. No2 is fine still. Voltage in 12.25.

JOB QAREA PUMP TEST DATE 1/31/91

PARTY CHIEF SKROBACE/CHAPPE PAGE

- 0430 Transfer discharge line from Tanker #2 to tanker #3 @ 11200 galls approximately 5400 galls in it. Tanker #3 is compartmentalized - Need to check on filling.
- 0455 Check dataloggers. Datalogger #1 is fine. Segment #5, interval 135. Datalogger #2. Voltage is 8.25 which seems low - could be due to jumper cable connectors having poor surface area connection. Currently on segment #2 interval 136.
- 0500 Check water level in SW-3. Is at 18.1'. Refuel Generator #2, while it is running. Seems to be running very smoothly. Let it run.
- 0545 Water level in SW-3 @ 18.1 feet
- 0625 SW-3 @ 17.95 Measure other wells
- 0700 Ho Hum....
- 0800 Switch fill pipe to another compartment of Tanker #3. Take VDA samples of water from SW-3, direct from discharge pipe. Total gallons pumped since start of test = 12300 - 030

JOB Q-AREA PUMP TEST DATE 1/31/91

PARTY CHIEF SKROBACE/CHAPPE PAGE

- = 11270 for 36 hours, average flow rate 5.27 gpm
- 0815 Unsuccessfully try to call Lab to get data from first 2 trucks - No reply.
- 0840 Truck squashes conduit going to SW-6 try to effect repairs. Put extra wood down to hold pipe.
- 0900 Call Lab (Jennings) and speak to Jeff. Verbally samples are below 10ppb PCE. Told him to fax copy to Carol Bowers when he has it. Call Carol + Ken Walker + notify of results being on the way. Check voltage on Datalogger #2. Reads 10.28 v.
- 0930 Check water levels in all wells.
- 1000 Still no word on disposal from Carol or Ken.
- 1015 Conduit to SW-6 smashed to pieces by large trucks, cable insulation cut, kinking wires. Try to board down wires and erect sign saying "drive to right / Drive to left". Hopefully will keep some of traffic off.

FATHER CHILD

PAGE

FATHER CHILD

Stop logging in logger #

2 @ 11:21

10:45 { Ch 1 = SW 4  
 { Ch 2 = SW 5  
 { Ch 3 = SW 6

10:55 { Ch 1 = SW 3  
 { Ch 2 = SW 2  
 { Ch 3 = SW 1  
 Ch 5 = SW 8

only one probe works (SW 3) 2nd  
 11:22 do not probe in  
 logger 2

16:28 discontinue probing  
 logger 1 & place them  
 on logger 2

17:10 commenced logging  
 of one logger and only  
 one probe (SW 3) but  
 all other probes did not  
 work, logger 2 was not  
 accepted then.

JOB Q-AREA PUMP TEST DATE 1/31/91

PARTY CHIEF SCROBACZ/CHAPPEL PAGE

No 1 is not working! No display  
- plenty of power but not at logger.  
11.19 volts at meter on power supply.  
Check connections - all seem fine.  
Check RV battery - connections good  
- Must be something inside the  
logger. Difficult to know how much  
we have missed or what time it quit.  
#1335 Mark returns w/phone calls Lars  
in MI. Doesn't have a lot of ideas  
- suggests disconnecting power then  
reconnecting it - This works -  
we have no idea if whether data  
has been stored or not. Set up  
logger to coincide with Datalogger  
No 2 - may be 1 reading out  
Keeck says data will be OK.

JOB

DATE

1/31/91

PARTY CHIEF

PAGE

1345 Take Martin to hotel

14.00 Return to site. Check  
data logger & the bloody  
thing is off ~~by~~ unplugged  
The logger several times  
& re-logs it after 2  
recordings, logger shuts off.  
I'm pissed by now not to  
mention frustration. No other  
cause of this crap?  
Fiddled around w/ this thing  
for about 2 hours. Can't  
get it to work. Therefore  
I disconnected logger #2  
and replaced ~~the~~ logger  
#1. So there will be  
no monitoring in SW 4, 5, 6  
except hourly readings w/  
the interface probe.  
Entered the program onto  
the logger once again for  
SW 1, 2, 3 & 8. Load & behold

FIN

JOB

DATE

1/31

JOB

1242

1/31

TIME	LOCATION	Time	DTW	Time	DTW
17:15	1	2033	750	2130	751
17:15	2	2032	797	2129	796
17:15	* 3	2030	1936	2121	1748
17:20	4	2037	757	2135	754
17:20	5	2036	612	2133	611
17:20	6	2040	798	2137	785
17:20	7	—	—	—	—
	8	2040	802	2140	800

Locat	1	2223	7.50	2225	7.50
SW 7	2	2222	7.97	2423	7.96
SW	3	2220	17.51	2422	17.19
SW	4	2229	7.51	2428	7.49
SW 4	5	2227	6.06	2427	6.04
SW	6	2232	7.81	2432	7.83
SW	7	—	—	—	—
SW	8	2234	8.02	2434	8.10

\* 2015 Adjust flow. water  
rose to 15.52 feet after surging  
tanks  
flow meter - 16130

1755 Tank Jones arrived to  
have trailer pick up  
about treatment plant  
Printed out data from logg

2050 pump 5.2 gpm

2108 Tank Jones arrived  
w/ empty tanks  
2115 take tank  
1038 to treatment water  
center. This tank will not  
return to the site

2200 Sampled tanks 7946

2345 Pick up Martin from Hotel

— 1/31/91 —



DATE \_\_\_\_\_

DAI

PAGE

PAGE

Location	Time	DTW	Time	DTW
SW 1	1817	7.52	1915	7.50
SW 2	1810	7.96	1913	7.96
SW 3	18:09	17.74	1911	17.57
SW 4	1816	7.68	1918	7.68
SW 5	1814	6.18	1917	6.15
SW 6	1819	8.11	1922	8.03
SW 7				
SW 8	1820	8.03	1924	8.02

# Q-AREA PUMP TEST DATE 2/1/91

SKROBACE / CHAPPEL PAGE

WELL	TIME	DTW	TIME	DTW
SW-1	0427	7.52	0531	7.53
SW-2	0425	8.00	0529	7.99
SW-3	0423	16.90	0528	16.23
SW-4	0436	7.69	0540	7.71
SW-5	0432	6.21	0538	6.22
SW-6	0440	8.17	0545	8.18
SW-8	0443	8.04	0547	8.05
	TIME	DTW	TIME	DTW
SW-1	0634	7.52	0732	7.52
SW-2	0632	7.98	0731	7.98
SW-3	0630	17.35	0729	18.18
SW-4	0642	7.70	0739	7.66
SW-5	0640	6.22	0737	6.20
SW-6	0645	8.14	0744	8.10
SW-7	-	-	-	-
SW-8	0647	8.04	0746	8.04

Datalogger working, all one channel of it. Make slight adjustment to gate valve to maintain flow from SW-3

0625 Check datalogger / water levels

# Q-AREA PUMP TEST 2/1/91

SKROBACE / CHAPPEL

0725 Check water levels  
 0800 60 hours into test 19620 gal pumped - 1030 start = 18590 gallons over the 60 hours = 5.16 gallons per minute average  
 0805 Check datalogger - still OK  
 0820 Get water levels  
 0845 Collect samples for 40 cc vials  
 For last much #1066 and  
 0925 pick up Mark at hotel. Mark drives to Lab for today's arrival. I stay at site collecting water levels.  
 0935 Manage to look over data printed out from logger #1 up to 1710 yesterday. We definitely have a slowdown in wells SW-2 and SW-1 to north of pumping well so this hasn't all been in vain. Difficult to say how this will all correlate, or how potential data gaps may impact the whole test.  
 1015 Check water levels  
 1125 Check water levels + datalogger

JOB Q-AREA PUMP TEST DATE 2/1/91

PARTY CHIEF SKROBACZ/CHAPPLE PAGE       

0015 Arrive at site following discussions.  
 - Frustration runs rampant.  
 0020 Check level in all wells 1-8

Well	TIME	DTW	TIME	DTW
SW-1	0029	7.49	0127	7.50
2	0026	7.95	0125	7.97
3	0023	16.98	0123	17.26
4	0037	7.51	0135	7.55
5	0035	6.05	0131	6.09
6	0041	7.87	0139	7.96
8	0045	8. -	0140	8.01
<hr/>				
	TIME	DTW	TIME	DTW
1	0225	7.50	0330	7.51
2	0222	7.97	0326	7.98
3	0220	17.04	0325	16.90
4	0231	7.59	0334	7.65
5	0229	6.12	0332	6.17
6	0235	8.04	0340	8.12
↓ 8	0238	8.02	0343	8.03

JOB

DATE 2/1/91

PARTY CHIEF SKROBACZ/CHAPPLE PAGE       

0100 Check to see if the one probe is working. Logger display is blank - it is sleeping. Check logger - Channel 1 - registers value - menu parameters OK. Put back to sleep between sample times.

0120 Total gallons pumped = 17550 - 1030 = 16520 since stop

0123 Check water levels in all wells

0210 Check datalogger - working OK. 4.85' measured on logger/probe. = 17.04 ft measured in well SW-3

0220 Check water levels

0240 Check generator. 1149 gals and is running pretty well.

0300 Check datalogger. OK. Channel 1 registers 5.04 - should be 16.85 measured and it is - was?!

0325 Check levels in all wells

0400 Put pump on to Generator #2 for a few hours to service #1. Monitor drawdown in SW-3. Stable @ 16.75'

0420 Check levels

0525 Check levels / datalogger

JOB Q-AREA PUMP TEST DATE 2/1/94

PARTY CHIEF SKROBACZ/CHAPLE

PAGE

WELL	TIME	DTW	TIME	DTW
SW-1	1228	7.52	1312	7.51
SW-2	1227	7.98	1311	7.98
SW-3	1225	20.08	1310	20.08
SW-4	1231	7.56	1316	7.59
SW-5	1230	6.12	1314	6.13
SW-6	1233	7.96	1320	8.00
SW-7	—	—	—	—
SW-8	1235	8.02	1324	8.03
SW-1	1411	7.53	1505	7.54
SW-2	1410	8.00	1504	8.03
SW-3	1409	20.09	1503	20.09
SW-4	1416	7.64	1507	7.70
SW-5	1414	6.17	1506	6.21
SW-6	1417	8.10	1509	8.19
SW-7	—	—	—	—
SW-8	1420	8.03	—	8.05

JOB

PARTY CHIEF

PAGE

14:00 changed to use tank 5  
had a reading on flowmeter  
of 21,430 before changing to tank  
6 (first tank)  
15:00 Take readings every hour break  
down equipment

WELL	TIME	DTW	TIME	DTW
SW-1	1613	7.55	1709	7.57
SW-2	1612	8.00	1708	8.03
SW-3	1610	20.03	1707	20.05
SW-4	1617	7.77	1713	7.79
SW-5	1615	6.27	1701	6.28
SW-6	1619	8.29	1717	8.32
SW-7	—	—	—	—
SW-8	1621	8.05	1719	8.05

18:15 Truck turns up to move  
water to treatment yard.  
18:15 Take water levels again!  
18:30 1st truck to treatment yard.  
Took part filled truck due to  
not having 4" → 3" reducer for  
tanker.

JOB Q-AREA PUMP TEST DATE 2/1/84

PARTY CHIEF SKLODACE / CHAPPEL PAGE

Well	Time	DTU	Time	DTU
SW-1	0827	7.52	0927	7.52
SW-2	0825	7.98	0926	7.97
SW-3	0823	18.27	0925	18.59
SW-4	0832	7.64	0931	7.59
SW-5	0830	6.17	0933	6.14
SW-6	0834	8.05	0920	8.02
SW-7	-	-	-	-
SW-8	0837	8.03	0917	8.02

Well	Time	DTU	Time	DTU
SW-1	1019	7.51	1127	7.51
SW-2	1018	7.98	1126	7.97
SW-3	1015	18.56	1125	18.39
SW-4	1028	7.57	1133	7.55
SW-5	1025	6.12	1130	6.11
SW-6	1034	7.91	1138	7.91
SW-7	-	-	-	-
SW-8	1039	8.02	1142	8.03

JOB DATE

PARTY CHIEF PAGE

1215 Switch to Generator #1  
 1225 Take water levels. Start to  
 break down equipment not needed  
 for test

# Q-AREA RECHARGE TEST

DOB

DATE

PARTY CHIEF SKROBY / MARTY PAGE

Well	TIME	DTU	TIME	DTU
SW-1	2051	7.55	2116	7.55
SW-2	2050	8.02	2114	8.03
SW-3	2044	8.88	2110	8.86
SW-4	2048	7.75	2120	7.72
SW-5	2046	6.26	2117	6.25
SW-6	2055	8.17	2121	8.14
SW-8	2056	8.05	2123	8.05

RECHARGE  
VALUES

Well	TIME	DTU	TIME	DTU
SW-1	2149	7.55	2227	7.55
SW-2	2148	8.02	2226	8.00
SW-3	2141	8.85	2225	8.83
SW-4	2146	7.70	2232	7.67
SW-5	2145	6.24	2230	6.21
SW-6	2153	8.10	2234	8.07
SW-8	2155	8.05	2235	8.05

Last Tanker leaves at  
2:20

DOB

2/1/91

PARTY CHIEF SKROBACZ / CHANUE

2016 Pump off @ 2016. Set up  
logger to read 1st minute each  
20 sec then each 30 sec for  
Total Gallons pumped for test  
= 23390 - 1030 (start reading)  
= 22360 galls in 72 1/4 hrs  
= 22360 gals / 4435 min = 5.06 gpm  
average

## LOGGER SET UP

Logger was set to record at  
the following intervals for recharge

	Readings	Interval	Total	Time
Sag 1	60	2	60	00.00
2	60	30	120	00.32
3	60	60	180	01.32
4	60	120	240	3.32
5	7	240	247	04.00

Total of four hours

Only one probe - in SW-3

2020

Continue to check levels in wells

JOB Q AREA PUMP TEST DATE 2/1/91

PARTY CHIEF SKROBACZ/CHAPPLE PAGE

WELL	TIME	DTW	TIME	DTW
SW-1	1818	7.56	1924	7.56
SW-2	1817	8.02	1923	8.02
SW-3	1815	20.10	1926	20.10
SW-4	1832	7.83	1919	7.79
SW-5	1830	6.32	1920	6.30
SW-6	1834	8.32	1917	8.28
SW-8	1836	8.07	1915	8.06

RECHARGE/PUMP OFF READINGS

WELL	TIME	DTW	TIME	DTW
SW-1	2000	7.56	2029	7.56
SW-2	1959	8.02	2028	8.02
SW-3	1955	20.10	2020	11.20
SW-4	1957	7.77	2032	7.74
SW-5	1956	6.29	2031	6.28
SW-6	2002	8.23	2037	8.19
SW-8	2004	8.05	2035	8.05

JOB Q AREA PUMP TESTS DATE 2/1/91

PARTY CHIEF SKROBACZ/CHAPPLE PAGE

1915 Check levels, for the penetrate time, prior to stopping pump + monitoring recharge  
 1955 Check levels for 1st time recharge/pump off SW-3

Time	Level	Secs
20-20:00	10.90	5
11:20' Orec	10.60	32
<del>11:40:00</del>	10.4	45
<del>21:00:30</del>	10.2	60
	10.10	71
	10.0	81
	9.90	93
	9.8	104
	9.7	119
	9.6	140
	9.5	160
	9.40	182
	9.30	221
	9.20	255
	9.1	293
	9.0	367

1	30	2	6030	00 01.00
2	60	120	9090	02 01.00
3	180	240	<del>240</del> 270	14 01.00
4	180	240	450	26 01.00
5	240	240	690	42 01.00
6	240	240	580	<del>58 01.00</del>
7	<del>240</del> 210	240		72 01.00
8	90	240		78 01

On site treatment ctr,  
 Office 444-4483

LP 20

left @ end of alley where we  
 1st stop. See transformer boxes  
 (approx in)

3" cam lock

5

## INDEX OF TABLES

Table I-SLOPE STAKE

Table II-TRIGONOMETRIC FORMULAE

## CURVE FORMULAE

Table III-INCHES TO DECIMALS OF A FOOT

Table IV-MINUTES IN DECIMALS OF A DEGREE

Table V-RODS IN FEET, 10THS AND 100THS OF FEET

Table VI-LINKS IN FEET, 10THS AND 100THS OF FEET



JOB

DATE

2/1/91

PARTY CHIEF

PAGE

well	Time	DW	Time	DW
SW-1	2315	7.75	00:02	7.54
SW-2	2313	8.03	00:01	8.00
SW-3	2311	8.83	2400	8.82
SW-4	2314	7.65	00:02	7.65
SW-5	2317	6.20	00:04	6.19
SW-6	2321	8.04	00:08	8.04
SW-7	—	—	—	—
SW-8	2324	8.05	—	—

Finished

Hopefully

JOB

DATE

PARTY CHIEF

PAGE

Ch 24



Pressure

Mon

HI 0739  
LO 0226  
HI 2012  
LO 1412

30.01

Tues

1/29

HI 0850  
LO 0236  
HI 2100  
LO 1520

30.15

Weds

1/30

HI - 0903  
LO - 0313  
HI - 2123  
LO - 1523

am

29.91

1m

29.74

For Reservations  
Call 1-800-HAMPTON

[illegible]

2. 27 pH  
11.9 T°

228

018 COND

ENVIRONMENTAL SCIENCE + ENGINEERING

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五ノ

**This Book is manufactured of a High Grade 50% Rag Paper having a Water Resisting Surface, and is sewed with Nylon Waterproof Thread.**

Q, AREA ADD. WORK  
(NAVY)

NORFOLK, VA.

PROJ. 44921150

PARTY CHIEF

TRANSIT

FIELD BOOK

Surveyors Distributors Inc.

Q AREA

DATE 10-14

BOWERS

PAGE 1A

15.5  
Depth to H<sub>2</sub>O 8.26'  
(TRC)  
Tot. Depth 43.68  
H<sub>2</sub>O Column 35.42

1 1/2 Drums PURGE H<sub>2</sub>O  
Drum #2  
Drum #3  
10-14-92

Q AREA

DATE 10-14-92

C.W. BOWERS PAGE 2

15:39 pH 7.4 7.65  
T° 15.8 clear  
Cond. -042

15:43 Generator quit  
Out of Gas

15:54 GAV had to get Gas  
for generator

Q AREA (over →)  
16:29 Return by to Bldg. 218

16:35 Begin pumping again

16:38 complete 55 gal.  
Pump rate = 3.9 gpm

16:40 complete pumping

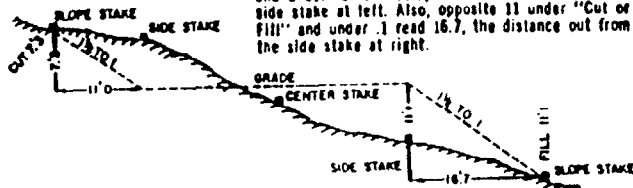
16:41 pH 7.76  
T° 15.8 clear  
Cond. -044

16:45 Sample #10 (DW-2) Filtr.  
16:48 Sample #9 (DW-2)

# DISTANCES FROM SIDE STAKES FOR CROSS-SECTIONING

Roadway of any Width. Side Slopes 1½ to 1.

In the figure below: opposite 7 under "Cut or Fill" and under .3 read 11.0, the distance out from the side stake at left. Also, opposite 11 under "Cut or Fill" and under .1 read 16.7, the distance out from the side stake at right.



	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	
Cut or Fill	Distance out from Side or Shoulder Stake										Cut or Fill
0	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	0
1	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9	1
2	3.0	3.2	3.3	3.5	3.6	3.8	3.9	4.1	4.2	4.4	2
3	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9	3
4	6.0	6.2	6.3	6.5	6.6	6.8	6.9	7.1	7.2	7.4	4
5	7.5	7.7	7.8	8.0	8.1	8.3	8.4	8.6	8.7	8.9	5
6	9.0	9.2	9.3	9.5	9.6	9.8	9.9	10.1	10.2	10.4	6
7	10.5	10.7	10.8	11.0	11.1	11.3	11.4	11.6	11.7	11.9	7
8	12.0	12.2	12.3	12.5	12.6	12.8	12.9	13.1	13.2	13.4	8
9	13.5	13.7	13.8	14.0	14.1	14.3	14.4	14.6	14.7	14.9	9
10	15.0	15.2	15.3	15.5	15.6	15.8	15.9	16.1	16.2	16.4	10
11	16.5	16.7	16.8	17.0	17.1	17.3	17.4	17.6	17.7	17.9	11
12	18.0	18.2	18.3	18.5	18.6	18.8	18.9	19.1	19.2	19.4	12
13	19.5	19.7	19.8	20.0	20.1	20.3	20.4	20.6	20.7	20.9	13
14	21.0	21.2	21.3	21.5	21.6	21.8	21.9	22.1	22.2	22.4	14
15	22.5	22.7	22.8	23.0	23.1	23.3	23.4	23.6	23.7	23.9	15
16	24.0	24.2	24.3	24.5	24.6	24.8	24.9	25.1	25.2	25.4	16
17	25.5	25.7	25.8	26.0	26.1	26.3	26.4	26.6	26.7	26.9	17
18	27.0	27.2	27.3	27.5	27.6	27.8	27.9	28.1	28.2	28.4	18
19	28.5	28.7	28.8	29.0	29.1	29.3	29.4	29.6	29.7	29.9	19
20	30.0	30.2	30.3	30.5	30.6	30.8	30.9	31.1	31.2	31.4	20
21	31.5	31.7	31.8	32.0	32.1	32.3	32.4	32.6	32.7	32.9	21
22	33.0	33.2	33.3	33.5	33.6	33.8	33.9	34.1	34.2	34.4	22
23	34.5	34.7	34.8	35.0	35.1	35.3	35.4	35.6	35.7	35.9	23
24	36.0	36.2	36.3	36.5	36.6	36.8	36.9	37.1	37.2	37.4	24
25	37.5	37.7	37.8	38.0	38.1	38.3	38.4	38.6	38.7	38.9	25
26	39.0	39.2	39.3	39.5	39.6	39.8	39.9	40.1	40.2	40.4	26
27	40.5	40.7	40.8	41.0	41.1	41.3	41.4	41.6	41.7	41.9	27
28	42.0	42.2	42.3	42.5	42.6	42.8	42.9	43.1	43.2	43.4	28
29	43.5	43.7	43.8	44.0	44.1	44.3	44.4	44.6	44.7	44.9	29
30	45.0	45.2	45.3	45.5	45.6	45.8	45.9	46.1	46.2	46.4	30
31	46.5	46.7	46.8	47.0	47.1	47.3	47.4	47.6	47.7	47.9	31
32	48.0	48.2	48.3	48.5	48.6	48.8	48.9	49.1	49.2	49.4	32
33	49.5	49.7	49.8	50.0	50.1	50.3	50.4	50.6	50.7	50.9	33
34	51.0	51.2	51.3	51.5	51.6	51.8	51.9	52.1	52.2	52.4	34
35	52.5	52.7	52.8	53.0	53.1	53.3	53.4	53.6	53.7	53.9	35
36	54.0	54.2	54.3	54.5	54.6	54.8	54.9	55.1	55.2	55.4	36
37	55.5	55.7	55.8	56.0	56.1	56.3	56.4	56.6	56.7	56.9	37
38	57.0	57.2	57.3	57.5	57.6	57.8	57.9	58.1	58.2	58.4	38
39	58.5	58.7	58.8	59.0	59.1	59.3	59.4	59.6	59.7	59.9	39
40	60.0	60.2	60.3	60.5	60.6	60.8	60.9	61.1	61.2	61.4	40

Q AREA

10/14

DATE: 10/14/14 C. W. BROWN PAGE 1

12. ON SITE 14:14  
13:30 (~) Picked up passes  
14:34 Site safety meeting

14:34 - 14:50 Staged + disconnected eq. dip

14:56 FLO BLANK \*192021

15:00 Rel. LINS. \*18

15:12 MOVE CNL DW-2  
CWA = 0 (in hole)  
CWA = 0 (breathing zone)  
15:14 mess. H<sub>2</sub>O levels (over →)  
15:27 Calibrate pH meter

mess

Sample

15:30 shut pump

15:32 shut pump

15:32 pH 9.88  
T<sub>o</sub> 15.9 °C

Cond - 167  
H<sub>2</sub>O sl. turbid

27.5  
21.35  
4.15  
14

DATE

PAGE

Q AREA

10-14-90

BOWERS

4

17:28 Start pumping

17:30 OVA Breathing ERE

17:32 pH 7.53  
Cond. -033 CLEAR  
TO 15.8

17:35 Stop pump  
pH 7.68  
TO 15.8 CLEAR  
Cond -038

17:37 Sample #6 (SW-8)  
- filtered

17:42 Sample #5 (SW-8)  
- unfiltered

17:50 Decent

17:59 Move on SW-5  
OVA

Q AREA

10-14

BOWERS

2A

1/2 Drum Pump H<sub>2</sub>O

Drum #2

10-14-92

10:00 Tried to call Ken Walker  
re access to surf. H<sub>2</sub>O  
sump. location  
(restricted area)  
- Ken gone for day  
Tried Susan Hunter  
- phone busy for  
20 min.

Q AREA

10-14-92

BOWERS


3

17:03 Decon

17:12 Move on SW-8

OVA = in hole > 1000  
GAU in level C as precaution  
to open hole

#17:17 OVA > 1000

Breathing zone  
OVA = 

17:22 Depth to H<sub>2</sub>O 7.77'  
(TDC)  
Total depth 24.65'  
Column 16.88

Should be ~ 7.18 min pump.  
time

17:28 pH 7.30 SC  
T<sub>5</sub> 5.8 TURBID  
Cond. 1008

Q Area

10-14-92

Bewers

6

18:24 sample #4 (SW 5)  
(filt.)

18:25 sample #3 (SW 5)  
(unfilt.)

18:26 sample #11 FD<sup>1</sup><sub>2</sub>  
(unfilt.) SW-5

18:28 Demob.

18:58 leave site



$$\begin{array}{r} 14 \\ 4 \overline{) 55} \\ 16 \end{array}$$

$$\begin{array}{r} 55 \\ 14 \\ \hline 41 \end{array}$$

1 Drum Purge  $H_2O$   
 Drum #1  
 10-14-92

Q AREA

10-14-92

Bowers

5

18:06 CVA w/plt. dead  
 Stand upwind to open well

18:07 Depth to  $H_2O$  5.71  
 (70C)

Total depth 25.37  
 column 19.66

Should be 8.46 min. pumping

18:13 Start pumping

plt 7.15  
 $T_o$  15.8  
 Cond. 002

V. Turbid

18:17 pH 7.26  
 $T_o$  15.9  
 Cond. -007

Sl. turbid

18:22 pH ~~7.26~~ 7.29  
 $T_o$  15.9 15.8 CLEAR  
 Cond. -007 -010

Stop pumping

18:22 sample #12 FD (SW-5)  
 Filt

FOR

DATE

9/24

FIELD CHIEF

PAGE

15:40 Mr Henderson allowed  
656 & H41 to utilize  
the water out of the fire hydrant  
as long as we have a backflow  
preventer on & keep the house  
out of the water when filling  
the tank.

16:00 Departed from the site to  
meet the drillers (Mark) at the press  
bldg. Carol & George located H<sub>2</sub>O<sub>2</sub>  
& isopropyl for decontamination.

Picked up more isopropyl  
& Fine Petroleum. Also  
reordered for empty drums  
to be delivered for development  
water.

MARKED ~~drilling~~ well and  
boring locations in AM

Harden. Huber Inc did not arrive  
to receive their passes until  
15:30 to 16:00. No drilling  
was performed today

Set up equipment for 9/55 &  
attempt to categorize all the  
sample containers. What a job  
this is (bb)

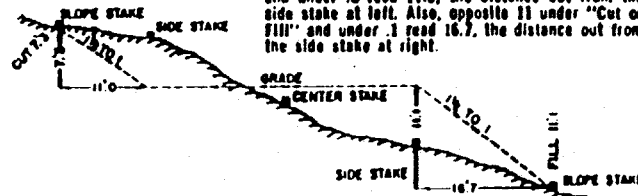
14:00 Carol met w/ R. Walker  
& marked the parking lot  
locations

15:30 Bill Conner approved  
& SE can take ~~photo~~ site  
photographs without naval  
supervision present.

# DISTANCES FROM SIDE STAKES FOR CROSS-SECTIONING

Roadway of any Width. Side Slopes 1½ to 1.

In the figure below: opposite 7 under "Cut or Fill" and under .3 read 11.0, the distance out from the side stake at left. Also, opposite 11 under "Cut or Fill" and under .1 read 16.7, the distance out from the side stake at right.



	0	.1	.2	.3	.4	.5	.6	.7	.8	.9	
Cut or Fill	Distance out from Side or Shoulder Stake										Cut or Fill
0	0.0	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.2	1.4	0
1	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9	1
2	3.0	3.2	3.3	3.5	3.6	3.8	3.9	4.1	4.2	4.4	2
3	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	5.9	3
4	6.0	6.2	6.3	6.5	6.6	6.8	6.9	7.1	7.2	7.4	4
5	7.5	7.7	7.8	8.0	8.1	8.3	8.4	8.6	8.7	8.9	5
6	9.0	9.2	9.3	9.5	9.6	9.8	9.9	10.1	10.2	10.4	6
7	10.5	10.7	10.8	11.0	11.1	11.3	11.4	11.6	11.7	11.9	7
8	12.0	12.2	12.3	12.5	12.6	12.8	12.9	13.1	13.2	13.4	8
9	13.5	13.7	13.8	14.0	14.1	14.3	14.4	14.6	14.7	14.9	9
10	15.0	15.2	15.3	15.5	15.6	15.8	15.9	16.1	16.2	16.4	10
11	16.5	16.7	16.8	17.0	17.1	17.3	17.4	17.6	17.7	17.9	11
12	18.0	18.2	18.3	18.5	18.6	18.8	18.9	19.1	19.2	19.4	12
13	19.5	19.7	19.8	20.0	20.1	20.3	20.4	20.6	20.7	20.9	13
14	21.0	21.2	21.3	21.5	21.6	21.8	21.9	22.1	22.2	22.4	14
15	22.5	22.7	22.8	23.0	23.1	23.3	23.4	23.6	23.7	23.9	15
16	24.0	24.2	24.3	24.5	24.6	24.8	24.9	25.1	25.2	25.4	16
17	25.5	25.7	25.8	26.0	26.1	26.3	26.4	26.6	26.7	26.9	17
18	27.0	27.2	27.3	27.5	27.6	27.8	27.9	28.1	28.2	28.4	18
19	28.5	28.7	28.8	29.0	29.1	29.3	29.4	29.6	29.7	29.9	19
20	30.0	30.2	30.3	30.5	30.6	30.8	30.9	31.1	31.2	31.4	20
21	31.5	31.7	31.8	32.0	32.1	32.3	32.4	32.6	32.7	32.9	21
22	33.0	33.2	33.3	33.5	33.6	33.8	33.9	34.1	34.2	34.4	22
23	34.5	34.7	34.8	35.0	35.1	35.3	35.4	35.6	35.7	35.9	23
24	36.0	36.2	36.3	36.5	36.6	36.8	36.9	37.1	37.2	37.4	24
25	37.5	37.7	37.8	38.0	38.1	38.3	38.4	38.6	38.7	38.9	25
26	39.0	39.2	39.3	39.5	39.6	39.8	39.9	40.1	40.2	40.4	26
27	40.5	40.7	40.8	41.0	41.1	41.3	41.4	41.6	41.7	41.9	27
28	42.0	42.2	42.3	42.5	42.6	42.8	42.9	43.1	43.2	43.4	28
29	43.5	43.7	43.8	44.0	44.1	44.3	44.4	44.6	44.7	44.9	29
30	45.0	45.2	45.3	45.5	45.6	45.8	45.9	46.1	46.2	46.4	30
31	46.5	46.7	46.8	47.0	47.1	47.3	47.4	47.6	47.7	47.9	31
32	48.0	48.2	48.3	48.5	48.6	48.8	48.9	49.1	49.2	49.4	32
33	49.5	49.7	49.8	50.0	50.1	50.3	50.4	50.6	50.7	50.9	33
34	51.0	51.2	51.3	51.5	51.6	51.8	51.9	52.1	52.2	52.4	34
35	52.5	52.7	52.8	53.0	53.1	53.3	53.4	53.6	53.7	53.9	35
36	54.0	54.2	54.3	54.5	54.6	54.8	54.9	55.1	55.2	55.4	36
37	55.5	55.7	55.8	56.0	56.1	56.3	56.4	56.6	56.7	56.9	37
38	57.0	57.2	57.3	57.5	57.6	57.8	57.9	58.1	58.2	58.4	38
39	58.5	58.7	58.8	59.0	59.1	59.3	59.4	59.6	59.7	59.9	39
40	60.0	60.2	60.3	60.5	60.6	60.8	60.9	61.1	61.2	61.4	40

9/24/50

CHIEF *Bowers / Bluford / Hale / York*

Received for Base passes (a)  
218.30

Spoke to Mr. O'Connell who informed him that we will be drilling on 9/25 or 9/26.

Mr. Hooker's trailer has been moved off of Area under house re-located in building X 218 (near McDonald's)

Mr. Ron Richman (ASG) allowed C. G. and C. V. to be parked within the Area

Richman's # 444 5627  
Hooker's # 444-4875

NAVY  
① AREA

490107

PARTY CHIEF  
TRANSIT  
FIELD BOOK

Survivors Distributors Inc

DATE

PAGE

PARTY FIELD

Drum	Inventory	Water
Well No	Soil	
DW-3	11	
DW-4	10	
DW-5	11	
DW-6	11	
DW-7	11	
DW-8	11	
SW-9	11	
SW-10	11	
Hydrof	11	
SW-1	11	
SW-2	11	
SW-3	11	
SW-4	11	
SW-5	11	
SW-6	11	
SW-7	11	
SW-8	11	
SW-9	11	
SW-10	11	
SW-11	11	
SW-12	11	
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SW-85	11	
SW-86	11	
SW-87	11	
SW-88	11	
SW-89	11	
SW-90	11	
SW-91	11	
SW-92	11	
SW-93	11	
SW-94	11	
SW-95	11	
SW-96	11	
SW-97	11	
SW-98	11	
SW-99	11	
SW-100	11	

11:45 Sample DW-6/Decon Br 6  
 12:00 Sample SW-10  
 12:10 Decon Equipment  
 Project 70 Gallons of water  
 from SW-10 and 55 Gallons  
 from DW-6  
 12:30 Purging DW-7  
 WL 9.32 TOL  
 Bolt 47.30 TOL  
 pH 15.74 15.81 15.88  
 Cond 1067 1283 12.99  
 Temp (°F) 58.8 62.0 61.5  
 12:45 Sample DW-7  
 12:55 Decon Equipment  
 13:15 Purging DW-8  
 WL 7.15 TOL  
 Bolt 33.299  
 pH 15.95 15.99  
 Cond 328 454  
 Temp (°F) 58.5 60.4  
 13:30 Sample DW-8  
 13:45 Decon Equipment

14:15 Purging DW-4  
 WL - 8.46  
 Bolt - 63.88  
 pH 15.40 - 14.32 - 12.02  
 Cond 1741 - 1628 - 18.30  
 Temp (°F) 58.6 - 59.4 - 58.4  
 14:45 Sample DW-4  
 14:55 Decon Equip  
 15:10 Purging DW-3  
 WL - 8.48 TOL  
 Bolt - 63.80 TOL  
 pH 7.01 - 7.33 - 7.24  
 Cond 1804 - 1692 - 15.86  
 Temp (°F) 53.2 - 57.7 - 57.8  
 15:45 Sample DW-3  
 15:55 Clean-up Decon  
 16:10 Equipment Blank Sample  
 16:20 Field Blank Sample  
 collected  
 16:40 Call O'Acce

REF

DATE 1/21/93

JOB

DATE

TIME

PAGE

1

PART

PAGE

8:00 Pat Hufis (ESE) and I get  
passes to enter Q-tron  
9:00 Dixon Equipment  
9:30 Sample Sediment 9-



Navy - Q Area

DATE 4/19/93

Navy - Q Area

DATE 4/19/93

Forrest

PAGE 1

Forrest

PAGE 2

			Sunny, 30, 601	16 16	DW-4	8.12	700	12"
14:00	Left Kulis (TSC) I				DW-2	8.11		12"
	arrived at site. We				SW-8	7.38		2'
	can only get 1 - long pass			16 35	GW-4	8.71		2'
	because the pass after			16 41	GW-3	7.83		2'
	lost our fax to get on			16 47	GW-2	9.31		2'
	base. <del>Down</del> at			16 51	GW-1	8.89		2'
15:00	Person DRS (under load			17:15	Pick up storm drain			
	indicator probe				grade adjacent to			
15:05	SW-5 WL	5.37	TOC		SW-1			
15:10	SW-3	7.97	6"	17:45	Can not locate storm			
15:15	DW-3	8.23	2"		drain grade on east			
	DW-1	8.12	1"		side			
	SW-2	7.18	2"	18:00	Left Site			
	SW-1	6.67	2"					
	SW-4	6.92	2"					
15:35	SW-7	5.76	2"					
15:42	DW-7	9.02	2"					
15:53	DW-6	7.18	2"					
	SW-10	6.57	2"					
	SW-9	7.18	2"					
	DW-5	6.98	1"					
16:15	DW-8	7.02	2"					
	SW-6	7.33						

Vauy - W. Green

DATE 1/20/93

JOB

DATE

CHIEF Forrest

PAGE 1

PARTY CHIEF

PAGE

8:00 Pat Hughes: C got a pump  
to get into base. Pass other  
opens at 8:00.

8:30 Set up on SW-9 and  
DW-6

9:00 SW-9 WL 6.68 TOL  
B.H. 34.90 TOL

9:10 DW-6  
WL 6.47 TOL  
B.H. 33.61 TOL

9:15 Can. done at meter

9:20 Purge DW-5  
pH 6.74 7.34 7.57  
Cond 1743 1006 1498  
T(°F) 55.7 57.2 55.2

9:45 Purge SS Gelling  
~~SW-9~~

Plt 7.49 7.73 7.82  
Cond 1868 1501 1540  
Temp 56.3 60.1 57.7  
Purged 70 Gelling

10:00 Sample DW-6  
10:15 Sample DW-9  
10:30 Reconn. Equipment  
11:00 Set up on BW-10 and DW-6  
11:10 Purge DW-6

7.30 WL TOL  
44.66 B.H. TOL  
pH 8.14 7.84 7.80  
Cond 1741 1884 1874  
T(°F) 60.2 61.7 62.0

11:30 Purge SW-10  
6.75 WL TOL

SW-10

SW-10  
pH 8.02 7.84 7.90  
Cond 1982 1910 1898  
Temp(°F) 62.5 63.1 63.7

1 Navy - Q Area

DATE 1/13/83

JOB

Navy - Q Area

DATE 1/13/83

TIME FORECAST

PAGE 1

TIME FORECAST

FORECAST

PAGE 2

7:00 We arrived at site

Recon Equipment

8:00 Set up on SW-10 and

DW-6 WL 6.99 TOL

BoH 44.64

SW-10

WL 6.50 TOL

32.55 BoH TOL

DW-6

8:10

8:25

pH 7.92 7.81 7.90

Cond 524 1288 1607

°F 578 608 618

8:30 SW-10

8:45

9:00

pH 8.02 7.95 7.91

Cond 1400 754 800

°F 59.4 64.5 64.8

9:00

Clon

10:00 PW-8 WL 6.79 TOL

BoH 33.25

pH 8.34 8.10 7.88

Cond 645 760 762

°F 59.1 61.0 62.7

10:00 10:10 10:20

10:30 Clon - Op Site Recon

Equipment

11:00 DW-7 WL 8.21 TOL

BoH 40.11 TOL

11:00 11:20 11:35

pH 9.70 8.68 8.49

Cond 960 1000 1050

T(°F) 64.7 64.4 63.7

12:30 PW-4 WL 7.13 TOL

BoH 63.20 TOL

pH 12.2 11.3 9.42

Cond 1220 1310 1610

T(°F) 40.6 66.2 80.4

TOP Navy - Q Area DATE 1/13/23 FOR

DATE

ENTRY CODE Forrest PAGE 3

PARTY CODE

PAGE

14.0	D4-3	WL	830	TOL
		BCH	645	TOL
		14.20	14.40	15.00
	pH	9.60	8.60	8.00
	Cond	2110	2750	2810
	T(°F)	52.7	54.8	60.8
	Took <sup>up</sup> Purged 80 Gallon of water Purged water very silty but cleared up (clean-up site)			
15.00	Piczo	WL	11.20	
		BCH	36.83	
	Top River			
16.45	Begin 1 Start Data Logger 1 Transducer in PVC 1 Transducer in Elizabeth River			
17.15	Clean-up Site 3 Cases Water Rope Drum Equipment			
18.00	Left Site			

May - Q Area

DATE 1/8/93

JOB

DATE

FOREST Forrest

PAGE 1

PARTY CREDIT

PAGE

Territorial Permit, 40's

- 7:00 The drilling & I arrive.  
Decon equipment
- 8:30 Set up on DW-8  
Start drilling at DW-8
- 11:00 Drilled to 40 feet. We  
had problems with running  
sands which we had to  
wash out of auger
- 11:15 Set screen from 15 to 40 feet  
Set sand up from 10 to 40 feet  
Set bentonite from 5 to 10 feet  
Set grout from 5 feet to  
surface. Set manhole
- 12:45 Clean up area
- 13:15 Clean up trailer area  
Decon Equip  
Take trash to Q-07 pump/gr  
Drillers pack-up equipment
- 14:15 At Q Trailer  
2 1/2 Cases Bottled water  
Isoprop - Antiseptic/Buckets (5)  
Drum Antiseptic  
1 Bag Green gloves  
2 Boxes of Blue gloves

Navy - Q Area DATE 1/12/83

JOB Navy - Q Area DATE 1/12/83

LAB. CHIEF Forrest

PAGE 1

PARTY CHIEF Forrest

PAGE 2

14:00 We arrived at site LESE's  
 Put Hoses & Pump  
 2-Inch brackish pump  
 1:30 Set 2-Inch PVC w/ 1-foot  
 screen into sediment at  
 end of Pier 18, the  
 PVC is pushed 2.5 feet  
 into sediment  
 15:30 Purge Pore w/ brackish  
 Water is clear  
 pH = 9.4, 50°F, Cond = 1850  
 15:35 pH = 9.0, 48°F, Cond 1820  
 15:45 " " "  
 Pull Pump  
 16:00 Water Level in Pier = 12.25 TOL  
 Water and sand Pier = 12.08 TOL  
 The sediment appear to be  
 Black Sand, Fine  
 16:15 Pull Pump  
 16:45 DW-5 70.7 WL TOL  
 40.20 TOL

1. 40 SW-9 7.32 WL TOL  
 3.76 BOM TOL  
 DW-5 - Pore Pate  
 pH = 7.14, Cond = 486, 62.5°F  
 17:00 7.77 = 1890 66.3  
 17:15 7.82 = 1840 66.1  
 SW-9 Pore Pate  
 17:00 7.50 1430  
 17:15 7.58 1300  
 17:30 7.56 1247 62.3  
 Purged 55 Gallons of water  
 from SW-9 and DW-5  
 18:00 Clean-Up, Transfer  
 water and left site

Navy - Q Area DATE 1/7/93

Forest

PAGE 1

7:00 The dollars and I arrived at site, I went to the utilities to clear site. The engineer the Electric (E) line <sup>was at</sup> the station North of the O's and 3000 North South parallel Reenter Road. Stream down, water line, and sewer were shown on my map. The utility people said they should be after lunch.

8:00 Began drilling SW-10 1 inch, 15 feet south of DW-6.

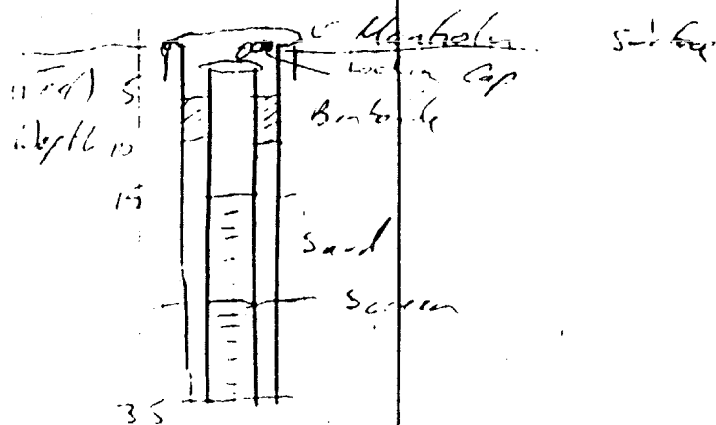
10:00 Drilled to 35 feet. Set Screen from 15 to 35 feet. Set Sand from 10 to 35 feet. Set Bentonite from 5 to 10 feet. Set Grout from 5 feet to surface. Set manhole and clean up site.

11:45 Decon Equipment

Navy - Q Area DATE 1/7/93

Forest

PAGE 2



SW-9 & SW-10

Well Installation Diagram

13:00 Go to utilities to get site

M-Scopod

14:00 Utilities M-Scopod moved

DW-7 and DW-8

Began drilling at DW-7

14:30 Drilled to 50 feet

Set screen from 15 to 50 feet

Set Sand from 10 to 50 feet

Set Bentonite from 5 to 10 feet

Set Grout from 5 feet to surface

Set manhole and clean up site

15:00 Decon Equipment

Map - 2 Area DATE 1/7/93

CHIEF Forester PAGE 3

JOB DATE

PAID FOR PAGE

1700 Clean up area  
and debris

Depth  
feet

Mark hole  
Surface  
Landing  
Cup

Grout/Binder

30

35

40

50

Binder

Surface

Grout

DW-



Navy - Q Area DATE 1-5-93

FOREST

PAGE 1

Rain, 50's

9:00 I arrived at site

9:30 Receive pass to enter site

10:30 Rollers arrive

11:30 Set up on DW-5 that  
is adjacent to HP-17

13:30 P. to 4. 35 to 45 feet

15:00 Set sand from 30 to 45 feet  
Taking bentonite soil from  
25 to 30 feet  
Bentonite - 6 out (1 to 20)  
from 25 feet to surface  
Set mantle

16:30 Piece equipment and clean up  
DW-5 site

17:00 Run out of water  
Left site

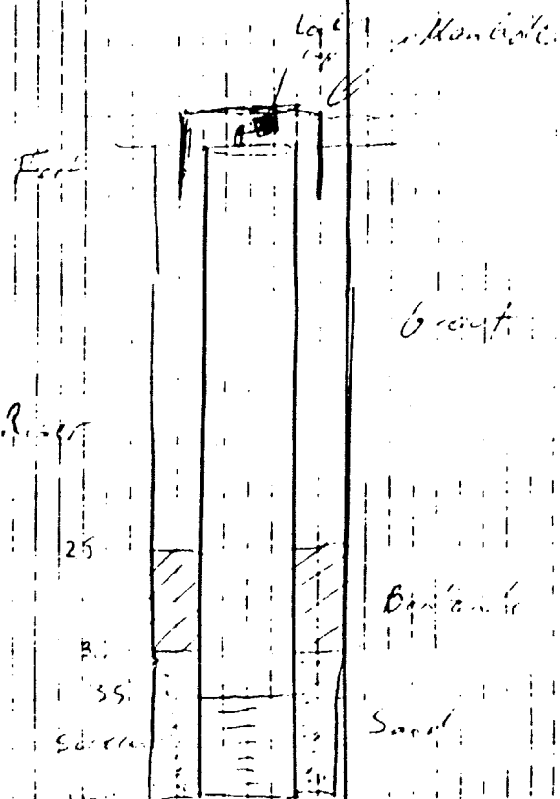
Navy - Q Area DATE 1-5-93

PARTY CHIEF

FOREST

PAGE

2



DW-5 : DW-6

Not to scale

Navy - G Area DATE 1-6-93

IOB Navy - G Area DATE 1-6-93

PARTY CHIEF Forrest PAGE 1

PARTY CHIEF Forrest PAGE 2

11:00 The debris and I arrived at site. Found a large amount of debris.  
 11:00 Set up on ~~Plot G~~ SW 9  
 11:15 The is 15 feet <sup>east</sup> of 45-5  
 11:15 Begin Drill Plot <sup>SW</sup> G SW 9  
 9:30 Found debris SW 9  
 Set screen from 45-35 feet  
 Sand is from 10 to 30 feet  
 Bentonite is from 5 to 10 feet  
 Gravel is from surface to 5 feet  
 Set manhole and clean up  
 12:30 Person Equipment  
 1:00 Move to Plot G  
 1:10 Drill Plot G  
 13:30 Drilled to 45 feet. There was  
 then 5 ft. gravel between  
 30 and 35 feet  
 14:00 Set screen from 35 to 45 feet  
 Set sand from 30 to 45 feet  
 Set Bentonite by frame pipe from  
 25 to 30 feet  
 Set gravel and manhole to  
 surface

15:00 Person Equipment  
 16:30 Too late to start another  
 monitor well. Clean the  
 well place the equipment and  
 monitor well location. Can  
 detect small irregularities.  
 from the surface.  
 He arrived at 18:30 to  
 drop off maps. Left  
 17:45 Left Site

May 12-21 1952 May 12-21 1952

Forest 1 Forest 2

1	HP-17-25	det. 1	CE at 2.25
2	1000	1000	1000
3	1000	1000	1000
4	1000	1000	1000
5	1000	1000	1000
6	1000	1000	1000
7	1000	1000	1000
8	1000	1000	1000
9	1000	1000	1000
10	1000	1000	1000
11	1000	1000	1000
12	1000	1000	1000
13	1000	1000	1000
14	1000	1000	1000
15	1000	1000	1000
16	1000	1000	1000
17	1000	1000	1000
18	1000	1000	1000
19	1000	1000	1000
20	1000	1000	1000
21	1000	1000	1000
22	1000	1000	1000
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96	1000	1000	1000
97	1000	1000	1000
98	1000	1000	1000
99	1000	1000	1000
100	1000	1000	1000

Wash - O. Area DATE 12-22-42 JOB

DATE

CHIEF Forrest

PAGE 1

PARTY CHIEF

PAGE

				mostly cloudy, 50°			
7:00	we arrived at site	HP-11					
	set augers out at HP-18						
	and decon equipment						
	shut off machinery						
8:05	Set up on HP-10						
8:30	Taking HP-10 25						
	1-16.2°C, pH 7.0, Col = 11,						
9:30	Taking HP-10 25						
	T = 17.2°C, pH = 7.62, Col = 87						
10:00	Taking HP-10 35						
	T = 17.9°C, pH = 6.89, Col = 279						
11:00	Taking HP-10 45						
	T = 16.2°C, pH = 6.97, Col = 251						
11:30	Set up 45 and BDC						
	Clean up and decon						
	equipment						
	To Home						
	4 boxes Per						
	1 box / 1.5 gal						
	4 Dixon B. mts, Bunker						
	2 Locks						
12:00	Left site						

Navy - Q Area

12-17-92

Navy - Q Area

12-17-92

Forest

PAGE 1  
cloudy 50%

Forest

PAGE 2

12 7:45 We arrived at site.  
8:00 SW-7 8:21 TCE WCL  
Purging 10 Gallons  
12 8:30 Sample SW-7  
9:00 Drive to pitting to  
get them over our next  
hydroponics. The manager  
ask the supervisor if  
someone came out to  
clear the utilities. The supervisor  
said no. The manager ask  
if someone can come out  
now. The utility clearing  
people came out at 9:30.  
9:30 Clear near hydroponic  
locations, the are now  
waiting for the hydroponic  
part.  
11:00 Taking HP-13-35  
T=18.9°C  
pH 7.27  
Cond 2000  
12:00 Begin HP-14-11  
15 HP-17-35 TCE = BDL

P. 11 water out of hole  
12:30 Sample HP-14-35  
Enough sample to find  
pH controlling and maximum  
13:00 taking HP-14-25  
pH = 7.81, T = 17.7, Cond = 446  
14:00 taking HP-14-35  
HP-14-25 = 18 ppb TCE  
HP-14-35 = 10 ppb TCE  
15:00 Continue and take  
hydroponic  
15:00 60 water came out of HP-14-35  
Beacon Hydroponic and took  
HP-14-50, Sample was found  
below detection limit's Beacon  
Equipment.  
17:00 Set up on HP-15. It rained  
it was clear for a while by 11:  
Utilities, many manhole covers  
that indicate an electric exposure  
to come below the cleared site.  
We decide to check the electric  
and about 10:00  
15:30 Left Site

May - 2 Area 12-18-92

Forest

1

DATE

PAGE

			Sunny, 40's
7:15	we arrived at site. I had		
	activities clear	HP-15	
8:00	Begin drilling	HP-15	
8:40	Hydro-mech	HP-15 15	
	T=15.6°C, pH=150, pH=7.5		
9:15	Taking Hydro-mech	HP-15 25	
	T=17.1°C, pH=50, pH=7.7		
	Person Equipment	HP-15 15	
	was at 2.3 pH TCE		
	HP-15 25 was at 100 pH TCE		
10:00	Taking	HP-15 35	
	T=15.6°C, pH=130, pH=8.04		
	T=15.2°C, pH=240, pH=8.15		
11:00	Taking	HP-15 45	
			←
11:15	Taking	HP-15 55	
	T=15.5°C, pH=95, pH=8.0		
12:00	Sample 22	BPL	
12:15	PH sample	A. dec.	
	equipment		
	Left Site		

Navy - Q Area

12-16-62

Forecast

1

Sunny 50

7:00 Everything appears at site  
We are going to take a  
Hydroponic at 35 feet

8:00 HP-11-35  
Temp. = 16.4  
Cond. = 2.96  
pH = 8.10

Contamin. detected proceeding to 45'

9:00 HP-11-45  
Temp. = 17.0  
Cond. = 15.65  
pH = 7.48

Contamin. detected proceeding to 55'

9:45 Work on HP 12-15 Begins  
HP-11-56' 1" of 1" brown sand  
was seen

10:00 HP-12-15

Temp. =  
Cond. =  
pH =

Not enough sample to take the  
readings. Contamination detected

Navy - Q Area

12-16-62

Forecast

2

Proceeding to 25'

10:15 Hydroponic at 55' begins on

10:35 HP 11-55'

Temp. = 17.9

Cond. = 25.4 @ 100 ARC

pH = 7.43

Field blank also taken due to printing  
being performed in carrier room by

Contamination detected. Proceeding to 65'

10:50 Beginning HP 12-25

11:05 Temp. = 17.2

Cond. = 10.17 @ 20 ARC setting.

pH = 7.47

Bad smell like sewage.

11:20 HP-12-25 Below detection  
limits. Zero equipment

11:25 Begin HP-11-65

Temp. = 17.3

Cond. = 2.40

pH = 7.33

Job Navy - Q Area DATE 12-4-92

FORECAST PAGE 3

12:15 Begin HP-13  
HP-11-65 is a 20,  
Take sample at 75 feet

12:45 HP-13-15  
T = 17.1°C  
pH = 7.12

13:30 HP-11-75  
T = 17.9°C  
Cond = 2980  
pH = 7.39

14:20 Purgin' well SW-3 in  
preparation for sampling.

Water level 8.27'

14:45 Sample taken found to be  
Below Det. Limits for TCE

15:18 Well Sampling SW-7 after purging  
Water level = 5.75'

15:30 Sampling

Job Navy - Q Area

DATE 12-4-92

FORECAST PAGE 4

14:00 Topping Hydroponch - more control  
HP-13-23

T = 14.1

Cond = 1190

pH = 7.49

Sample was at 3 ppb of TCE.  
Hydroponch price that holds  
the screen completely broke  
We can get it part by 4/1/93  
temporarily



Navy - Q Area 12-13-43

Forrest

cloudy, 300

9:00 We arrived at site - Forrest  
 9:10 Begin HP-9-49  
 9:30 Hy. depth 4 ft. 10-12 ft.  
 10:30 Taking hydroponic HP-9-25  
 10:00 Earth samples at 10 ft. TCE  
 values (250 & 395 ppb)  
 We need to take sample  
 out of auger and about 2  
 30 ft. Both samples  
 but not hard enough under to  
 take pH, Temp and Conductivity  
 From Forrester II with the old  
 drill now at the hydroponic  
 well (Dib-4) adjacent to  
 HP-9-25. From well  
 is currently taking hammer drill  
 soil samples at 3 ft. and 5 ft.  
 feet  
 11:30 HP-9-30  
 T = 14.1°C, pH = 7.77  
 12:00 Dr. 30 ft. 4 ft. test. Then  
 hydroponic  
 T = 14.4°C, pH = 7.43 Cond = 40.1

Navy - Q Area 12-13-43

Forrest

2

13:00 HP-9-45 TCE = 5 ppb  
 We are going to 55 ft.  
 14:00 HP-9-55  
 T = 12.8°C, pH = 7.47 Cond = 46  
 Sample is clean. Then again  
 15:15 Begin at HP-5-15  
 T = 16.5  
 Cond = 2.02  
 pH = 7.74  
 16:35 HP-5-25  
 T = 13.8°C  
 Cond. = 4.68  
 pH = 7.98  
 17:35 HP-11-15  
 T = 15.5  
 Cond. = 1.28  
 pH = 7.29  
 18:00 TCE Sample  
 HP-11-25

Navy - Q Area

DATE - 7-42

P.B.

DATE

Forest

NO. 3

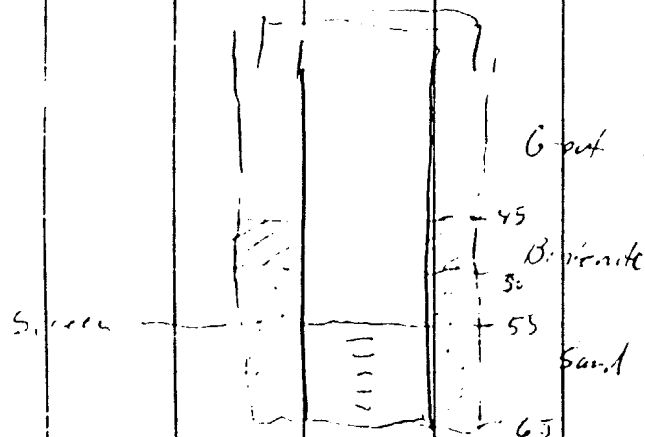
DATE

PAGE

Frank G. and Lane  
 completed the soil borings.  
 Frank Fitzgerald and the second  
 rig drilled back ground  
 well DW-4 to 65 feet.  
 Screen is from 55 to 65 feet  
 Sand is from 50 to 65 feet  
 Biotite is carried from  
 45 to 50 feet. Grout was  
 carried from 45 to surface.  
 15 inch manhole was grouted  
 around the well.

~~7-42~~ H.P. ~~DA~~

Well Construction Diagram



~~AA~~ DW-3 and DW-4

Navy - Q Area

12-13-92

Forest

1

Windy, cloudy, -°

7:15 We left around 7:15. P's  
are clean equipment and the  
GC is being calibrated

8:30 Set up on 7-15

9:00 Take sample HP-7-15

Take 10 ml sample water

to get pH, calc Temp

Decon hydroponics

10:30 Take sample HP-7-25

T = 16.9, Cond = 2.10, pH = 1.87

10:35 Beta hydroponics can

out with about 100 ppl

11:00 Taking sample HP-7-35

T = 12, Cond = 2.39, pH = 2.80

12:00 Decon Equipment Problems

with some samples

13:00 Taking sample HP-7-45

pH = 7-45, Cond = 2.10

pH = 7.74, T = 16.3, Cond = 2.10

14:00 Taking sample HP-7-55

T = 12.5%, Cond = 17.24, pH = 7.55

15:00 Sample was found broken  
at the bottom

Navy - Q Area

12-13-92

Forest

2

16:00 Decon Equipment

17:00 Left Site

May - C Area

12-15-92

Forest

PAGE 1

7:10 We arrived at site

8:00 Taking Hydroponic HP-3  
 HP-3-15  
 Cond. 10.3, Temp. 10.5, pH = 7.04  
 Decid. Hydroponic

9:00 Taking Hydroponic HP-3-25  
 Temp. 10.5  
 Cond. = 3.43  
 pH = 7.72  
 Lab. in field, to water  
 Decid. Hydroponic. Move to  
 Hydroponic HP-4

10:00 Taking HP-4-15  
 pH = 7.59  
 Temp. 12.2  
 Cond. Not enough sample to take reading

11:30 Taking HP-4-25  
 pH = 7.17  
 Temp. 10.6  
 Cond. = 4.41

12:30 HP-4-25 is found  
 below the collection limits

May - C Area

12-15-92

Forest

PAGE 2

14:00 Start drilling at HP-1

14:30 No water at 15 feet, go to 20 ft  
 HP-1-20, Root Color  
 pH = 7.1, 11.7°C, 740 Cond  
 Decid. Hydroponic

14:40 Sampling HP-1-30

15:30 Sample HP-1-20 & 15 ft pH 7.6  
 Sample HP-1-30 & 30 ft pH 7.6  
 Decid. Hydroponic and take

16:00 Sample HP-1-40  
 T = 13.4, Cond. = 1700, pH = 7.84

17:00 Sample HP-1-50  
 T = 13.9, Cond. = 770, pH = 7.69  
 Found Gate and Base  
 arrived at 13:00 and  
 completed 2 soil borings (503-15  
 for TPH, Tank Samples  
 and the second drill core  
 completed Dec-3, Sample 11  
 from 35 to 65 feet. Sand is from  
 30 to 65 feet. Bentonite is from 45 to 50  
 feet. Set marker and go to  
 surface

Navy - Q Area

DATE 12-12-72

Navy - Q Area

DATE 12-12-72

Forrest

1

Forrest

2

17:00 Frezard, Jackson, G. S. and E. arrived at site. Forst  
decon decontaminate equipment.  
6.6 is being calibrated.

8:30 Set up on HP-6

8:40 Taking HP-6-15  
pH = 6.8  
Temp = 12.1°C  
Cond = 798

9:00 Decon Hydroponics  
Taking HP-6-25  
pH = 7.72  
Cond = 500  
Temp = 9.6

9:10 3 pH TCE, take another  
hydroponics

11:00 Hydroponics HP-6-35  
pH = 7.85  
Cond = 1.17  
Temp = 14.7

12:00 Begin drilling at HP-8 after  
decon equipment  
Took HP-8-15; not enough

Rain, windy, no sun

washed to get pH, Cond (Temp)

12:30 Decon Hydroponics &amp; try again

12:00 Not enough water for sample

Decon Hydroponics and try at  
25 feet

13:45 Hydroponics sample HP-8-25

T = 16.0°C, Cond = 398, pH = 7.27

TCE = 2 ppm

Decon = 50 to 35 feet

15:00 Hydroponics HP-8-35

T = 15.0, Cond = 240, pH = 7.8

15:30 Leads are below column head

Decon equipment

16:00 Begin drilling at HP-2-

17:00 No sample at 15' at 3 TCE

T = 11.2°C, pH = 7.48, HP-2-20

Dug out 1 foot sample at 20 feet

17:30 Could not get water in HP-2-

18:00 Decon Hydroponics and

take HP-2-35

pH = 7.84, 12.4°C, 281 = C

TCE was 27 ppb

Taking Hydroponics sample

HP-2-45 after decon

For May 2 test, DATE 12-2-72

WIP

DATE

For Forest

PAGE 3

DATE

DATE

Sample was found at 20 ppb  
for HP-2-45.

Proton Equipment and tag at  
HP-2-55. We water in  
Hydroponic Proton Equipment  
and tag at HP-2-65.

Sample came in at 41 ppb  
higher than the sample at  
45 test. We cannot leave  
rig overnight since we are  
blocking cars in the parking  
lot. We abandoned hole  
because it is dark and  
left etc.

At HP-2, there was a gray  
clay or a sludge at 20  
test. It had a strong  
odor not like a real Oppen  
It had a pink color.

11 May - 12 May 1972

Forest

7:00 Forest temperature 15.5°C, 15.5°C  
 Jackson (55E) & Jones (25E)  
 and A. ...  
 8:00 ...  
 9:00 ...  
 10:00 ...  
 11:00 ...  
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11 May - 12 May 1972

Forest

pH = 7.75  
 Cal = 239.0  
 Temp = 11.4°C  
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Q-Area

12-11-92

Forest

3

11.2	11.3-65			
	pt	7.52		
	containing	2.790		
	temperature	11.2		
11.8	11.3-65		11.2	
	containing			
	temperature			
	containing			
	temperature			



27.  
Navy - 2 Area 11 12-2-92

Forrest

Sunny, 40's

13.00 Frank Fragner, Glenn Jackson  
and I get vehicle passes  
to enter Norfolk Naval Base

14<sup>00</sup> including the C. Hwy (6 SE)

14<sup>00</sup> We get the Reg. to enter  
2-Area from Building 218

Glenn Jackson asks us to get  
compress air for the 6-C  
he drives out up the 2-Area  
Area

14.00 Set 1 T-1000

14.10 Set 1 T-1000

14.20 Set up recorder logger

14.30 Set 1 T-1000

14.40 Set 1 T-1000

Data will be collected every

60 minutes for 30 days

1.30 We left site

Navy - Q Area

12-10-92

Forecast

1

7:30 GSE, Glenn Jackson & I arrived at site. The Public Utilities are supposed to be at the Q-Area to clear boring locations. The duties are stream cleaned by Glenn Jackson to collect the 1st bear chromatograph (1st).  
 9:00 Duties finish stream cleaning equipment. I called Paul Forsythe (Bury) to inform that public utilities are not to check their progress.  
 10:00 I called Bury on progress of Public Utilities.  
 10:30 I called Bury on progress of Public Utilities. The Bury said they will be at the Q-Area after lunch (12:30).  
 11:00 Fine Peterson dropped off 12 55-batteries from Paul Forsythe arrived. Frank Forsythe Glenn Jackson

JOE Navy - Q Area

DATE 12-10-92

PAGE 1 Forecast

PAGE 2

went to get hydrogen for the OLT  
 12:00 Lunch  
 12:30 Public Utilities are still not here. I call Public Utilities on stream (the battery) 1st message. The battery unit to pick up the new message.  
 14:30 Public works said they would be here by now. Paul Forsythe & I went down over to public works to check the Burying pits are clear.  
 15:00 Public Utilities are clear on the Q-area except for stream water. Public Works promise to be at the Q-Area at 8:00. We go down to start adjacent to OLT-1.  
 16:00 Towards Burying, high winds and heavy rain. Burying  
 17:00 Burying: Sutter meeting with everybody  
 17:30 Left Site

15:02 pH 7.18  
Cond -00-00  
T° 11.7°C

15:06 pH 7.07 u.s.l.  
Cond. -00.3 turbid  
T° 11.7°C

stop pumping

15:07 Sample #2  
~~DE~~ SW-2 (Filt.)

15:10 Sample #1  
SW-2 (Unfilt.)

15:15 Demob  
left supplies in trailer  
for Dec. field work

-looked for drum dolly  
(-will move drums in Dec.)  
→ couldn't find one that  
would

BRING DEWM DATA  
IN DEC.

15:45 returned QHCC log  
to 218

15:50 left site

Send samples to Mike Walsh  
Denver office +  
Charles Frier Gainesville

4-1

DATE

DATE

DATE

DATE

PAGE

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PAGE

11:30 Took trip blank sample  
\*23

12:09 Took Equip blank \*18

12:26 pH 7.73  
Cond - 0.15  
T° 11.7°C

12:45 pH 7.61  
Cond - 0.23  
T° 11.7°C

Stop pumping

12:45 sample \*8  
(pH - 7.61)

12:47 Sample \*7  
Dew - 7 unfilt.

13:15 mob. to Pile area.

13:42 Took sample - SURFW2  
13:46 \*22

1 Drum PURGE  $H_2O$   
 Drum #8  
 10-15-92

~~13:42~~

~~13:45~~ pH 7.57  
 Cond ~0.8  
 TO 11.9

13:57 Took sample  
 SURFW 1 K.H. \*14  
 SURFW unfil. \*13

14:45 Move on SW-2

14:49 depth to  $H_2O$  3.60  
 (TOC)  
 Total depth 24.34

should pump ~ 7 1/2 min.

14:55 Start pumping  
 pH 7.05  
 Cond. -0.8 V TURBID  
 TO 11.7°C

Q AREA

10-15

BOWERS

7

8:15 Called Ken Walker re  
access to surf. H2O samp.  
location

- ~~not~~ coming in later

8:30 Told Ken Walker again  
- not coming in until 8:45  
- left message ~~also~~ for  
Susan Hester to call  
- missed Susan's return  
call - tried her #  
- busy

8:40 Told Ken Walker  
- not in yet  
- no answer on Susan  
Hester's phone  
- left message for Ken to  
page me as soon as  
he gets in

9:35 Pick up passes

9:50 Pick up G. Hester trip  
Call Ken Walker re  
access to surf H2O location

4 DRUMS PURGE H<sub>2</sub>O  
+ 2 DRUMS #4, 5, 6, 7, 7A  
10-15-92

Q AREA

10-15-92

BOWERS

8

9:55 Arrive on site  
H+S mtg.

10:00 Stage, decen

10:22 move on DW-1

WA out of hydrogen  
open well in level C

10:29 Depth to H<sub>2</sub>O 8.01  
(T<sub>xx</sub>)

Tot. Depth 43.89

10:43 pH 7.60  
Cond -0.30  
T<sub>o</sub> 11.8

SI turbid

11:06 Stopped purging (no more drums)

11:19 Started on 3rd drum

11:25 Stopped pumping

11:35 GKH to get add. drums



7-21

TIME

DATE

FIELD CODE

PAGE

14:50

Spoke w/ Joe. Over  
will have people meet me on  
site tomorrow to check  
offices

HAVING TROUBLE w/ SAMPLE BOTTLES  
may not have all of them  
- some don't have preser.  
- some caps off

TRIP BLANKS NOT FIXED!

TA-1 PD

is actually field dup.  
for TA-4 boring

Had to hand auger over  
TA-4 orig. boring to get  
enough water for field  
dup.

Finished indexing boring  
locations.

Q Area

9-25

Brewer / Shockey / George / H.H.

07:10 arrived on site

set up gear and began  
drilling @ 08:58 on boring  
TA-4.

Performed 4 more soil  
borings (TA-1, TA-2, TA-3, &  
TA-5) and completed  
one shallow well (SW-5)  
H.H. utilized their drill  
rig to collect the soil samples  
top of the first few TA borings.  
~~that~~ 68' felt there was too much  
down time <sup>during borings</sup> because we would  
to wait & see if there was  
enough sample per spoon to fill  
our sample containers. Majority  
of these borings had to have  
additional sampling (H.H.  
changes per spoon)

DATE

9-25

TIME

PAGE

SW-5 location is within a shallow depression where it appears a lot of water will accumulate. Therefore I instructed HHI to place the manhole 2' to 3" above existing grade.

Having difficulty to get things to block off the two wells (SW-6 & SW-7) within the parking lot. HHI blocked off the area around SW-8 & SW-9 this evening.

Best soil samples trip blocks & 52B to be in coolers w/ ice & sealed w/ custody tags.

9.25

strengthened and sample bottle  
problem. Turns out only a  
sample couldn't be found, but  
we just remembered is one of  
the extra bottles

CEMIC sent us 125 water  
to fill trip blanks

13:07 to 13:50  
Agreed PP-11

14:50 to 15:10  
Agreed PP-6

Took field blanks 15:45, 15:50

13:20 Took soil equip blank

DATE \_\_\_\_\_

PAGE

7.26

As HHI sat the well down  
 hole, a thunderstorm struck.  
 They tried to stop sand down in  
 the hole & it seems we created a  
 plug above the screen. We thought  
 the approved hole changed  
 water from the <sup>live</sup> hydrant down  
 the hole in an attempt to  
 break the sand down to pack.  
 I instructed HHI to pull the  
 well out & secure it again  
~~for some~~ They as they pulled  
 the auger up they broke  
 the well up a ~~lot~~ many  
 cable (Haggerty 11). ~~The~~  
~~the~~ they pulled out the auger  
~~down~~ out, placed a plug  
 in the lead auger & it worked  
 10 & 5 ft. End for the day!

(Carol B. walked very well & young people's utility people; all these.

9/26

9:00? was not cleared because  
~~vehicle~~ vehicle covers it.

George V. will not be onsite  
9:17-80.

13:27 to 13:50

Assigned PP-11

14:50 to 15:16

Assigned PP-6

17:00 took sent equip blank.

DAN BAXTER VISITED SITE

JOB

DATE

G. Area

9-26

TIME

TIME

Bones / Skelton / George / 442

07:05 Arrived on site  
 Decon<sup>spl</sup> spoons, sampling eq.

~~08:00~~

08:00 Began drilling (SW-4) and  
 completed the well @ 09:15

HHI mobilized 10 DW-2  
 at 13:00. Between 09:15 to 13:00  
 HHI grouted SW-5 & down  
 all drilling equipment

13:00 Began drilling DW-2.  
 Continuous sampling was done  
 from 18 feet to 45 feet to  
 detect the exact depth of any  
 clay we might encounter. The  
 purpose was to case the  
 upper aquifer from the lower.  
 We did not find the clay  
 layer that is present in SW-4 &  
 SW-5. A thin clay wet  
 layer of organics was located  
 between 1.5 ft to 21.5 feet.

9/27

Finances/Shipping/HH

Arrived on site @ 07:00

Completed SW-2 @ ~~12:00~~ 13:00

Bushed for lunch.

Down spoons & drilling eq.

Started SW-8 @ 15:30

I completed the well by 18:00

Continued after driller (Fuller)  
to follow all safety rules (rubber  
gloves, no smoking, etc).

Encountered a strong odor (organic)  
and high volatile readings on the  
CUT from the spoon sample @  
15.0 to 20.0 feet.

George V. departed from site  
yesterday evening & will be back  
on site 9-28-90.

Carol B. will not be on site  
9-28-90



4-27

~~sent replacement for NLS sample  
to lab. In file group is NLS  
sample 5E5T.11. The lab  
accepted them.~~

14.77 to 15.17

Accepted PP-3

Sample PP-6-1 FD is actually  
held dup for PP-3 1

15.55 to 17.13

Accepted PP-2

Class 3 hours

D

Q Area

9/5/8

~~Q Area~~ / Shubey / Robinson / H/F 1

Arrived on site @ 09.00

After decom drilling eg H/F 2  
began drilling SW 3 @ 09.15  
(6" well)

10.00 J. Hyman of DKAIO  
arrived onsite to remove 33  
of the existing drums onsite to  
a different location off site.

Received approval from C. Brewer  
to install the screen of SW 3  
above the water to detect the  
presence of any floating product  
in the petroleum product area.

13.45 Began drilling SW 6  
There were a few problems with running  
rod but not serious. Lost bit  
The well to 25 ft.

9-28

Placed beds on all wells,  
before leaving the site for the  
weekend.

Star-6 will need a manhole  
cover & grout to 10 ft.

Took soil equipment from site  
Hillocks (2 sets)

11:40 SEBHM-1

NNQIIVIAW \* 7

-For samples taken previous  
day (9-27)

15:45 SEBHM-2

NNQIIMAW \* 8

-For samples taken today

12:05 Tool requirement MS

For SEBTA-1

NNQTAW \* 7

10-1-96

Brew / Shohy / H.H.

Arrived on site 07:00  
H.H. did not arrive until 08:30  
They replaced A. Fuller (driller)  
with a new one (Brew)  
There are two new helpers. George  
Johnson. But, who was here  
last week will be supervising  
the new crew. I discussed the  
safety requirements to the new  
crew before starting work.

Installed Su-7. This well  
is very dirty, a lot of silt.

Installed Su-2. We did  
not hit any confining layer  
(clay).

Drilled Su-1 to 135 feet  
and sampled to 100 feet. Could  
not sample from 123-125  
because it was 18:00 and  
at last to leave.

177  
Navy - Q Area 12-7-92

Forrest 1

		Sunny, 40's
13.00	Frank Fragano, Glenn Jackson and I get vehicle passes to enter Norfolk Naval Base including the College (CASE)	
14.00	We get the Reg to enter Q-Area from Building 218	
	Glenn Jackson went to get compress air for the GC	
	the drivers set up the Recon Area	
14.00	Site 1	7.00
14.10	Site 1	8.00
14.20	Set up modular logger	
	File 1 (Transducer 1) in	
	Dir-1, Transducer 2, Site 1	
	Data will be collected every 60 minutes for 30 days	
14.30	We left site	

Navy - Q Area

12-10-42

Forrest

1

7.30 GSE, Glenn Jackson & I arrived at site. The Public Utilities are supposed to be at the Q-Area to clear boring locations. The drillers are stream cleaning. Glenn Jackson is calibrating the Geomagnetic (G.L.)

9.00 Drillers finish disassembling equipment. I called David Langley (Lang) to inform that public utilities are not to check their progress.

10.00 I called Lang on progress of Public Utilities.

10.30 I call Lang on progress of Public Utilities. The Lang said they will be at the Q-Area after lunch (12.00)

11.00 Fire Petroleum dropped off  
12 55-Langley's Pumps  
Paul Forsgren arrives  
Frank Forsgren Glenn Jackson

JOB Navy - Q Area

DATE 12-10-42

PARTY NAME Forrest

PAGE 2

went to get hydrogen for the OHT

12:00 Lunch

12:30 Public Utilities are still not here. I call Public Utilities on Steeles (Mr. Callaway). I left message. The drillers wait to pick up the more riggers

14:30 Public works said they would be here by now. Paul Forsgren & I went down over to public works to check the engineering prints ourselves.

15:00 All utilities are clear on the Q-area except for storm water. Public Works promise to be at the Q-Area at 8:00. We get permission to start adjacent to Bt-1.

16:00 Tornado blowing, high winds and heavy rain continue

17:00 Health & Safety meeting with everybody

17:30 Left Site

12-11-92

Forest

- 7:00 From Thompson (555) L. 5m  
Jackson (555) L. 5m (555)  
and H. 5m (555)  
Glen Jackson (555)  
10:30 D.W. - 3. 5m (555)  
D.W. - 3. 5m (555)  
11:00 D.W. - 3. 5m (555)  
11:30 D.W. - 3. 5m (555)  
12:00 D.W. - 3. 5m (555)  
12:30 D.W. - 3. 5m (555)  
13:00 D.W. - 3. 5m (555)  
13:30 D.W. - 3. 5m (555)  
14:00 D.W. - 3. 5m (555)  
14:30 D.W. - 3. 5m (555)  
15:00 D.W. - 3. 5m (555)  
15:30 D.W. - 3. 5m (555)  
16:00 D.W. - 3. 5m (555)  
16:30 D.W. - 3. 5m (555)  
17:00 D.W. - 3. 5m (555)  
17:30 D.W. - 3. 5m (555)  
18:00 D.W. - 3. 5m (555)  
18:30 D.W. - 3. 5m (555)  
19:00 D.W. - 3. 5m (555)  
19:30 D.W. - 3. 5m (555)  
20:00 D.W. - 3. 5m (555)  
20:30 D.W. - 3. 5m (555)  
21:00 D.W. - 3. 5m (555)  
21:30 D.W. - 3. 5m (555)  
22:00 D.W. - 3. 5m (555)  
22:30 D.W. - 3. 5m (555)  
23:00 D.W. - 3. 5m (555)  
23:30 D.W. - 3. 5m (555)  
24:00 D.W. - 3. 5m (555)

12-11-92

Forest

- pH = 7.75  
Cul = 339  
Temp = 11.4°C  
13:00 D.W. - 3. 5m (555)  
13:30 D.W. - 3. 5m (555)  
14:00 D.W. - 3. 5m (555)  
14:30 D.W. - 3. 5m (555)  
15:00 D.W. - 3. 5m (555)  
15:30 D.W. - 3. 5m (555)  
16:00 D.W. - 3. 5m (555)  
16:30 D.W. - 3. 5m (555)  
17:00 D.W. - 3. 5m (555)  
17:30 D.W. - 3. 5m (555)  
18:00 D.W. - 3. 5m (555)  
18:30 D.W. - 3. 5m (555)  
19:00 D.W. - 3. 5m (555)  
19:30 D.W. - 3. 5m (555)  
20:00 D.W. - 3. 5m (555)  
20:30 D.W. - 3. 5m (555)  
21:00 D.W. - 3. 5m (555)  
21:30 D.W. - 3. 5m (555)  
22:00 D.W. - 3. 5m (555)  
22:30 D.W. - 3. 5m (555)  
23:00 D.W. - 3. 5m (555)  
23:30 D.W. - 3. 5m (555)  
24:00 D.W. - 3. 5m (555)

11-11-92  
Q-Area

11-11-92

100

100

Forest

3

100

100

11-11-92

11-11-92

11-11-92

7.52

11-11-92

2790

11-11-92

11.2

11-11-92

11-11-92

11-11-92

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11-11-92

11-11-92

11-11-92

11-11-92



Navy - Q Area

DATE 12-12-72

Navy - Q Area

DATE 12-12-72

Forrest

PAGE 1

Forrest

PAGE 2

Rain, windy, no sun

17:00 Freygang, Jackson, GSI and I arrived at site. Finish decon decontamination equipment. GSI is being calibrated

8:30 Set up on HP-6

8:45 Taking HP-6-15  
 pH = 6.8  
 Temp = 12.1°C  
 Cond = 798

9:00 Percen Hydroponics  
 Taking HP-6-25  
 pH = 7.72  
 Cond = 500  
 Temp = 9.6

9:30 3 ppb TCE, take another Hydroponics

11:00 Hydroponics HP-6-35  
 pH = 7.85  
 Cond = 1.17  
 Temp = 14.7

12:00 Begin drilling at HP-8 after decon equipment  
 Took HP-8-15; not enough

water to get pH, cond. (Tanj)

12:30 Percen Hydroponics try again

13:00 Not enough water for sample  
 Decon Hydroponics and try at 25 feet

13:45 Hydroponics sample HP-8-25  
 T = 16.0°C, Cond = 398, pH = 7.37  
 TCE = 2 ppb

Percen 50 to 35 feet

15:00 Hydroponics HP-8-35  
 T = 16.0, Cond = 240, pH = 7.8

15:30 Leads are below column level  
 Decon equipment

16:00 Basin drilling at HP-2-

17:00 No sample at 15' at 3 Tiers  
 T = 7.2°C, pH = 7.48 HP-2-20  
 Drilled 1 foot sample at 20 feet

17:30 could not get under HP-2-35

18:00 Percen Hydroponics and take HP-2-35.  
 pH = 7.84, 12.4°C, 281 = C  
 TCE was 27 ppb  
 Taking Hydroponics sample HP-2-45 after decon

For Mary Q. Log DATE 12-12-92

TOP

DATE

For Forest

PAGE 3

PAGE 3

PAGE

Sample was found at 20 ppb  
for HP-2-45.

Recon Equipment and log at  
HP-2-55. We water in  
Hydroponic Recon Equipment  
and log at HP-2-65.

Sample came on at 41 ppb  
higher than the sample at  
45 feet. We can not leave  
rig overnight since we are  
blocking cars in the parking  
lot. We abandoned hole  
because it is dark and  
left etc.

At HP-2, there was a gray  
clay or a siltstone at 20  
feet. It had a strong  
odor but not a real O ppm  
It had a good odor.

Navy - Q Area

12-13-92

Forest

1

Windy Windy, "

7:15

We all arrived at site. P's are  
are ocean equipment and the  
GC is being calibrated

8:00

3rd up on 7

9:00

Take sample HP-7-15

There is no sample water  
to get pH and Temp

Ocean hydroponics

9:30

Take sample HP-7-25

T = 16.9, Cond = 210, pH = 1.87

10:30

Beta hydroponics corals

cut with about 100 ppl

11:00

Taking sample HP-7-35

T = 12, Cond 339, pH = 2.80

12:00

Ocean Equipment Problems

with running samples

13:00

Taking Sample HP-7-45

HP-7-25 had 65 ppl at GC

pH = 2.74, T = 16.3, Cond = 211

14:00

Taking Sample HP-7-55

T = 12.6, Cond 1724, pH = 2.55

5:00

Sample was found below  
detection limits

Navy - Q Area

12-13-92

Forest

2

16:00

Ocean Equipment

17:00

Left Site

May - Q Area

12-15-11

Forest

PAGE 1

7:10 We arrived at site  
 8:00 Taking Hydroponic HP-3  
 HP-3-15  
 Cond. 103, T = 10.1, pH = 7.01  
 Decon Hydroponic  
 9:00 Taking Hydroponic HP-3-25  
 Temp. 10.5  
 Cond. = 3.43  
 pH = 7.72  
 Calibrated pH meter  
 Decon Hydroponic. Move to  
 Hydroponic HP-4  
 10:00 Taking HP-4-15  
 pH = 7.59  
 Temp. 12.2  
 Cond. Not enough sample to take reading  
 11:30 Taking HP-4-25  
 pH = 7.17  
 Temp. 10.6  
 Cond. = 4.41  
 12:30 HP-4-25 is turned  
 below the detection limits

May - Q Area

14-12-11

Forest

PAGE 2

14:00 Start drilling at HP-1  
 14:30 No water at 15 feet, so to 20 ft  
 HP-1-20, Feet Clear  
 pH = 7.1, 11.7°C, 740 Cond  
 Decon Hydroponic  
 14:45 Sample HP-1-30  
 15:30 Sample HP-1-20 & 15 pH 7.5E  
 Sample HP-1-30 & 30 pH 7.5E  
 Decon Hydroponic and test  
 16:00 Sample HP-1-40  
 T = 13.4, Cond = 1700, pH = 7.84  
 17:00 Sample HP-1-50  
 T = 13.9, Cond = 770, pH = 7.69  
 Frank Gale and Dave  
 arrived at 13:00 and  
 completed 2 soil borings (SB-1 & SB-2)  
 for TPH, Frank Fragano  
 and the second drill crew worked  
 completed DB-3, Screen is  
 from 35 to 65 feet. Sand is from  
 30 to 65 feet. Bentonite is from 45 to 50  
 feet. Set marker and govt to  
 surface

Navy - Q Area 12-13-92

Forrest

cloudy, 503

7:00 We arrived at site - Forrest  
 Began equipment  
 8:00 Began HP-9-45  
 8:30 Hydropanch HP-9-45  
 9:30 Taking Hydropanch HP-9-25  
 10:00 Both samples with TCE  
 values (low 250 to 395 ppb)  
 We need to clean sample  
 out of auger and about 2  
 30 feet. Both samples  
 did not have enough water to  
 take pH, Temp and Conductivity  
 Found Fracture is with the other  
 well near drilling the hydropanch  
 well (Dib-4) adjacent to  
 HP-9-25. Found water  
 is currently taking hammer drill  
 soil samples at 31.5 and 80.7  
 feet.  
 11:30 HP-9-35  
 T = 16.1°C, 195 = Cond, pH = 7.75  
 12:00 D. 1. 37.5 45 feet, Began  
 hydropanch  
 T = 16.4°C, 195 = 7.43 Cond = 404

Navy - Q Area 12-13-92

Forrest

2

13:00 HP-9-45 TCE = 5 ppb  
 We are going to 55 feet  
 14:00 HP-9-55  
 T = 12.8°C, pH = 7.72, Cond = 4.46  
 Sample is clean. Began equipment  
 15:15 Began at HP-5-15  
 T = 16.5  
 Cond = 2.02  
 pH = 7.74  
 16:35 HP-5-25  
 T = 13.8°C  
 Cond. = 4.68  
 pH = 7.98  
 17:35 HP-11-15  
 T = 15.5  
 Cond. = 1.28  
 pH = 7.29  
 18:00 TCE Sample  
 HP-11-25

Navy - Q Area

DATE 5-42

NO.

DATE

Forest

PAGE 3

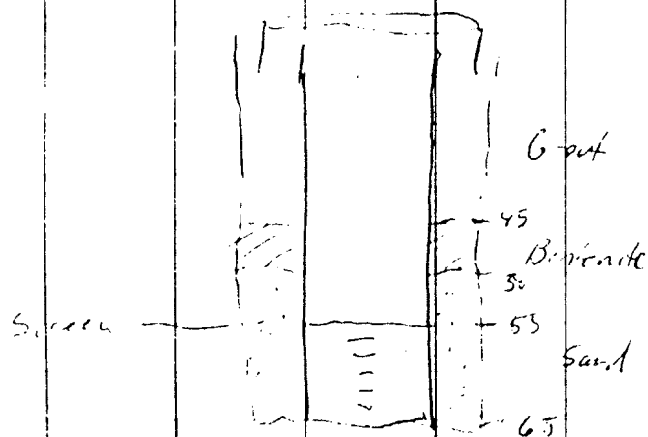
DATE

PAGE

Frank Galt and Dave  
completed the soil borings.  
Frank Frayana and the second  
rig drilled background  
well DW-4 to 65 feet.  
Screen is from 55 to 65 feet  
Sand is from 50 to 65 feet  
Bentonite is slurred from  
45 to 50 feet. Grout was  
slurred from 45 to surface  
is 2 inch mesh was grouted  
around the well

~~File HP-DA~~

Well Construction Diagram



AA DW-3 and DW-4

Navy - Q Area

12-16-92

Forest

1

Sunny, 50

7:00 Equipment arrives at site  
We are going to take a  
Hydropunch at 35 feet

8:00 HP-11-35  
Temp. = 16.1  
Cond. = 2.96  
pH = 8.10

Contaminant detected proceeding to 45'

4:00 HP-11-45  
Temp. = 17.0  
Cond. = 15.65  
pH = 7.48

Contaminant detected proceeding to 55'

9:45 Work on HP-12-15 Begins  
HP-11-50' 1 ring 11. Lit. in. Sand  
w/ shell

10:00 HP-12-15  
Temp. =  
Cond. =  
pH =

Not enough sample to take the  
readings. Contamination detected

Navy - Q Area

12-16-92

Forest

2

Proceeding to 25'

10:15 Hydropunching @ 55' begins on  
10:35 HP-11-55'

Temp. = 17.9  
Cond. = 25.4 @ 100 ATC  
pH = 7.43

Field blank also taken due to printing  
being performed on carrier near by.

Contamination detected. Proceeding to 65'

10:50 Beginning HP-12-25

11:05 Temp. = 17.2  
Cond. = 10.17 @ 20 ATC setting.  
pH = 7.47  
Bad smell like sewage.

11:20 HP-12-25 Below detection  
limits. Iron. Equipment

11:25 Begin HP-11-65

Temp. = 17.3  
Cond. = 2400  
pH = 7.33

JOB Navy - Q Area DATE 12-10-92

FORECAST

PAGE 3

12:15 Begin HP-13  
HP-11-45 is ~ 20,  
take sample at 75 feet

12:45 HP-13-15  
T = 17.1°C  
pH = 7.72

13:30 HP-11-75  
T = 17.9°C  
Cond = 2980  
pH = 7.39

14:20 Purging of well SW-3 in  
preparation for sampling.

Water level 8.27'

14:45 Sample taken found to be  
Below Det. Limits for TCE.

15:10 Well Sampling SW-7 after purging  
Water level = 5.75'

15:30 Sampling

JOB Navy - Q Area DATE 12-10-92

FORECAST

PAGE 4

14:00 Trying Hydroponch - piece critical  
HP-13-25

T = 14.1

Cond = 1190

pH = 7.49

Sample was at 3 ppb of TCE.  
Hydroponch piece that holds  
the screen completely broke  
We can get it put by 4/5  
tomorrow



Navy - Q Area

DATE 12-12-92

Navy - Q Area

DATE 12-17-92

FORECAST

PAGE 1  
cloudy 50's

FORECAST

PAGE 2

- 12 7:45 We arrived at site.  
8:00 SW-7 8:21 75C WCL  
Pursing 10 Gallons  
12 8:30 Sampling SW-7  
9:00 Drive to utilities to  
get them clear and next  
hydroponics. The manager  
ask the supervisor if  
someone came out to  
clear the utilities. The supervisor  
said no. The manager ask  
if someone can come out  
now. The utility clearing  
people came out at 9:30.  
9:30 Clear next hydroponic  
locations, we are now  
waiting for the hydroponic  
part.  
11:00 Taking HP-13-35  
T=18.9°C  
12:30 pH 7.37  
Cond & 20.5°C  
12:50 Begin HP-14  
15 HP-14-35 TCE = BDL

- Pull augers out of hole  
12:45 Sample HP-14-15. Not  
enough sample to find  
pH, conductivity and temperature  
13:00 Taking HP-14-25  
pH = 7.81, T = 17.7, Cond = 446  
14:00 Taking HP-14-35  
HP-14-25 = 10 ppb TCE  
HP-14-35 = 10 ppb TCE  
15:00 Continue and take  
hydroponic  
15:00 No water came out of hydroponics  
Becon Hydroponic and tank  
HP-14-50, Sample was found  
below detection limit's Becon  
Equipment.  
17:00 Set up on HP-15. Although  
it was clear for utility by 11:  
Utilities, many manhole exists  
that indicate an electric line pass  
so went below the cleared site.  
We decide to check the utilities  
and about tomorrow  
15:30 Left Site

May - Q Area

12. 18 92

101

Forecast

1

PARTY LIST

PAGE

				Sunny, 40's
7:15	we arrived at site. I had			
	utilities clear	HP-15		
8:00	Begin drilling	HP-15		
8:40	Hydrofracture	HP-15-15		
	T=13.5°C, Load=130, pH=7.5			
9:15	Taking Hydrofracture	HP-15-25		
	T=17.1°C, Load=510, pH=7.7			
	Perforation Equipment	HP-15-15		
	was at 2.53 ppg TCE			
	HP-15-25 was at 100 ppg TCE			
10:00	Taking	HP-15-35		
	T=13.6°C, Load=130, pH=8.04			
	T=13.2°C, Load=240, pH=7.13			
11:30	Taking	HP-15-45		
				←
12:15	Turning	HP-15-55		
	T=15.2°C, Load=970, pH=9.0			
13:00	Sample 33	BPL		
14:00	Rolling up	with debris		
	equipment			
	Left Site			

16



JOB Name: O. Area DATE 12-22-92

JOB

DATE

FIELD CHIEF Forecast

PAGE 1

PARTY CHIEF

PAGE

7:00 We arrived at site. Mostly cloudy, site  
 set augers out of HP 18  
 and decom. equipment  
 adequate measurements  
 8:15 Set up on HP-10  
 8:30 Taking HP-10 15  
 $T = 16.9^{\circ}\text{C}$ ,  $\text{pH} = 7.8$ ,  $\text{Cond} = 111$   
 9:30 Taking HP-10 25  
 $T = 17.2^{\circ}\text{C}$ ,  $\text{pH} = 7.62$ ,  $\text{Cond} = 87$   
 10:10 Taking HP-10 35  
 $T = 17.9^{\circ}\text{C}$ ,  $\text{pH} = 6.89$ ,  $\text{Cond} = 249$   
 11:00 Taking HP-10 45  
 $T = 16.9^{\circ}\text{C}$ ,  $\text{pH} = 6.97$ ,  $\text{Cond} = 251$   
 11:30 HP-10 45 and BPL  
 Clean up and decom.  
 equipment  
 To Town  
 4 boxes Heli  
 1 box / 2 bags  
 4 Brown Bunches, Bunches  
 2 Locks  
 12:00 Left site

Navy - Q Area DATE 1-5-93

Forrest

PAGE 1

Rain, 50's  
 9:00 I arrived at site  
 9:30 Receive pass to enter site  
 10:30 Drillers arrive  
 11:30 Set up on DW-5 that  
 is adjacent to HP-17  
 13:30 P. to the  
 From 35 to  
 45 feet  
 15:00 Set sand from 35 to 45 feet  
 Turned bentonite sand from  
 25 to 30 feet  
 Bentonite - Gout (11:20)  
 from 25 feet to surface  
 Set mantle  
 16:30 Packed equipment and clean up  
 DW-5 site  
 17:00 Ran out of water  
 Left site

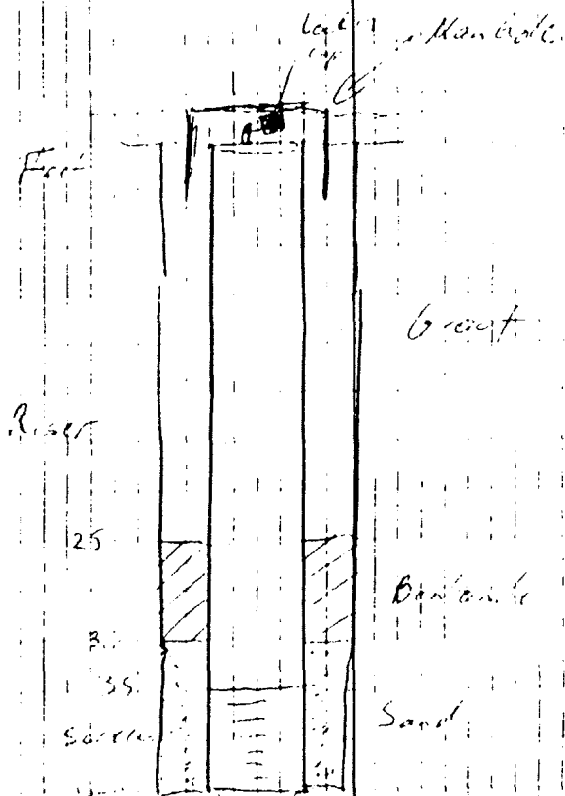
Navy - Q Area DATE 1-5-93

PARTY CHIEF

Forrest

PAGE

2



DW-5 : DW-6

Mantle Gout

Navy - A Area DATE 1-6-93

THREE Farrest PAGE 1

11:00 The others and I arrive at site. Finish design operation  
 12:00 Set-up on ~~FW~~<sup>SW</sup> 9  
 14:15 Begin Drill, ~~FW~~<sup>SW</sup> 9  
 9:30 Finish drilling SW-9  
 Set screen from 15-35 feet  
 Sand is from 15 to 35 feet  
 Bentonite is from 5 to 10 feet  
 Gravel is from surface to 5 feet  
 Set manhole and clean-up  
 10:150 Recon Equipment  
 1:00 Move to DW-6  
 1:10 Drill DW-6  
 13:30 Drilled to 45 feet. There was  
 then 5 ft. gravel between  
 30 and 35 feet  
 14:00 Set screen from 35 to 45 feet  
 Set sand from 30 to 45 feet  
 Set Bentonite by frame pipe from  
 25 to 30 feet  
 Set gravel and manhole to  
 surface

JOB Navy - A Area DATE 1-6-93

PARTY CHIEF Farrest PAGE 2

15:00 Recon Equipment  
 16:30 Too late to start another  
 monitor well. Cleaned  
 and placed the equipment and  
 monitor well location on  
 sketch map supplied by  
 John. The well is about  
 100 feet from the  
 MC arrived at 18:30 to  
 drop off maps. King  
 17:45 Left Site

Navy - Q Area DATE 1/7/93

Forrest

PAGE 1

7:00

7:00

Prizzle, SD's  
The drillers and I arrived at site, I went to the utilities to clear site. The engineer the Electric (E) line possibly the station North of the B's and 3000 North-South parallel Reenter Road. Stream crossing, water line, and sewer was shown on my map. The utility people said they should be after lunch.

8:00

Began drilling SW-10  
4 inches 15 feet south of DW-6

10:00

Drilled to 35 feet Set Screen from 15 to 35 feet Set Sand from 10 to 35 feet Set Bentonite from 5 to 10 feet Set Grout from 5 feet to surface Set manhole and clean-up site

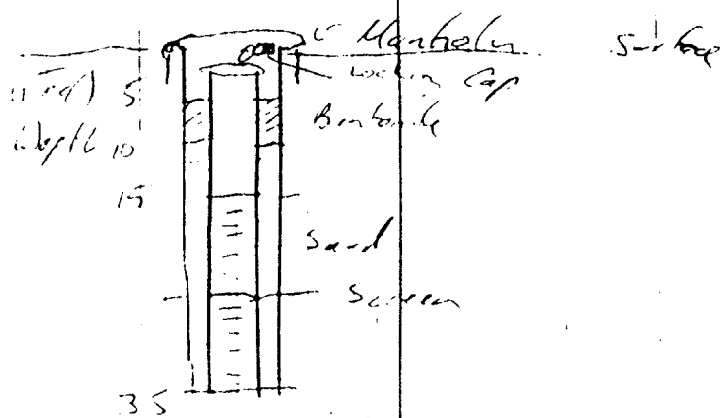
11:45

Decon Equipment

Navy - Q Area DATE 1/7/93

Forrest

PAGE 2



SW-9 & SW-10

Well Installation Diagram

13:00 Go to utilities to get site

M-Scopod

14:00 Utilities M-Scopod moved

DW-7 and DW-8

Began drilling at DW-7

14:30 Drilled to 50 feet

Set Screen from 15 to 35 feet

Set Sand from 10 to 35 feet

Set Bentonite from 5 to 10 feet

Set Grout from 5 feet to surface

Set manhole and clean-up site

15:00 Decon Equipment

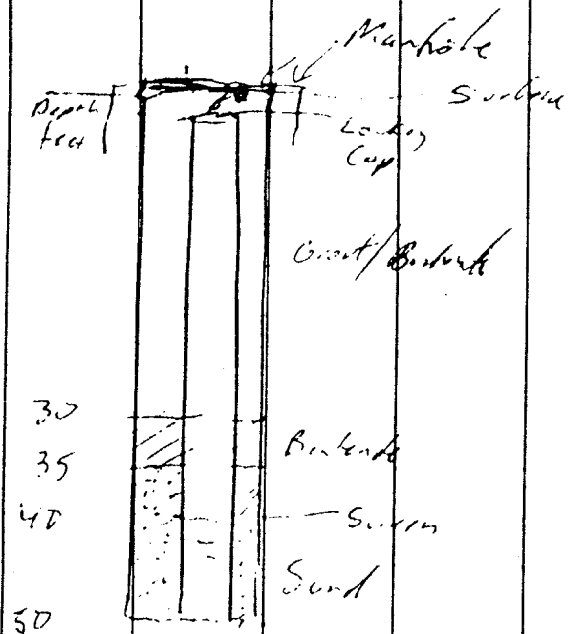
Name - Q Area DATE 1/7/93

JOB \_\_\_\_\_ DATE \_\_\_\_\_

CHIEF Forester PAGE 3

PART DET PAGE

1712 Clear-up area  
and debris site



DW-7



May - Q Area

DATE 1/8/93

JOB

DATE

FOREMAN Forrest

PAGE 1

PARTY CHIEF

PAGE

Turnout Range 40's

- 7:00 The driller & I arrive.  
Decon equipment
- 8:30 Set up on DW-8  
Start drilling at DW-8
- 11:00 Drilled to 40 feet. We  
had problem with running  
bands which we had to  
wash out of auger
- 11:15 Set screen from 15 to 40 feet  
Set sand at from 10 to 40 feet  
Set bentonite from 5 to 10 feet  
Set grout from 5 feet to  
surface. Set manhole
- 12:45 Clean-up area
- 13:15 Clean up trailer area  
Decon Equip  
Take trash to Q-99 dumpster  
Driller's pack-up equipment
- 14:15 At Q Trailer  
2 1/2 Cases Distilled water  
Iso-prop-nitric/Buckafs (5)  
Drum Policy  
1 Bag Grain gloves  
2 Boxes of Blue gloves

Navy - Q Area DATE 1/12/83

JOB Navy - Q Area DATE 1/12/83

PARTY CHIEF Forrest

PAGE 1

PARTY CHIEF Forrest

PAGE 2

SO<sub>2</sub>, Foggy

14:00 We arrived at site (EST's  
Pt Harker & Decon  
2-Inch brunters pump  
1:30 Set 2-Inch PVC w/ 1-foot  
screen into sediment at  
end of Pier 14, the  
PVC is pushed 2.5 feet  
into sediment  
15:30 Purge Pore w/ brunters  
Water is clear  
pH = 9.4, 50°F, Cond = 1850  
15:35 pH = 9.0, 48°F, Cond 1820  
15:45 " " "  
Pull Pump  
16:00 Water Level in Pier = 12.25 TOC  
Water level outside Pier = 12.08 TOC  
The sediment appears to be  
Black Sand, Fine  
16:15 Decon Equip  
1  
16:45 DW-5 7.07 WL TOL  
40.20 TOL

1. SW-9 7.32 WL TOL  
3.70 BPH TOL  
DW-5 - Purge Rate  
pH = 7.14, Cond = 486, 62.5°F  
17:00 7.77 = 1890 66.3  
17:30 7.82 = 1940 66.1  
SW-9 Purge Rate  
17:00 7.50 1930  
17:15 7.58 1300  
17:30 7.56 1247 62.3  
Purged 55 Gallons of water  
from SW-9 and DW-5  
18:00 Clean-Up, Transfer  
water and left site

Navy - Q Area DATE 1/13/23

JOB Navy - Q Area DATE 1/13/23

CHIEF Forecast

PAGE 1

CHIEF Forecast

PAGE 2

7:00 We arrived at site  
Bacon Equipment

8:00 Set up on SW-10 and  
DW-6 WL 6.99 TOL  
BOH 44.64

SW-10  
WL 6.50 TOL  
32.55 BOH TOL

DW-6 8:10 8:25  
pH 7.92 7.81 7.90  
Cond 524 1607  
pF 578 60.8 61.8

8:30 SW-10 8:41 9:00  
pH 8.02 7.95 7.91  
Cond 1400 754 800  
pF 59.4 64.5 64.8

9:00 Clean

10:00 DW-8 WL 6.79 TOL  
BOH 33.25  
pH 8.34 8.10 7.88  
Cond 645 760 7.62  
pF 59.1 61.0 62.7  
10:00 10:10 10:20

10:30 Clean - Up Site ! Bacon  
Equipment

11:00 DW-7 WL 8.21 TOL  
BOH 40.11 TOL  
11:00 11:20 11:35  
pH 9.70 8.68 8.49  
Cond 960 1000 1050  
T(pF) 64.7 64.4 63.7

12:30 DW-4 WL 7.13 TOL  
BOH 63.20 TOL  
pH 12.2 11.3 9.42  
Cond 1220 1310 1610  
T(pF) 60.6 60.2 60.4

TOP

Navy - C Area

DATE 1/13/83

JOB

DATE

FIELD CHIEF

Forrest

PAGE

3

PARTY CHIEF

PAGE

14:00

DW-3

WL

830

TOL

BOH

645

TOL

14:20

14:40

15:00

pH

9.60

8.60

8.00

Cond

2110

2750

2810

T(OF)

52.7

54.8

60.8

Took out Purgel 80 Gallon of

Water Purgel water very silty

but cleared up Clean-Up Site

15:00

Piczo

WL

11.26

BOH

36.83

Top River

16:45

Begin i Start Data Logger

1 Transducer in PVC

1 Transducer in Elizabeth

River

17:05

Clean-Up Site

3 Cases Water

Rope

Drum Equipment

18:00

Left Site

Navy - Q Area

DATE 1/19/93

Navy - Q Area

DATE 4/19/93

Forrest

PAGE 1

Forrest

PAGE 2

		Sunny, 30, 66	16:16	DW-4	8.12	TOC	2"
14:00	Lat Highs (ESE) : I			DW-2	8.41		2"
	arrival at site. We			SW-8	7.38		2"
	can only get 1 - by pass		16:35	GW-4	8.79		2"
	because the pass effect		16:41	GW-3	7.83		2"
	lost our fax to get on		16:47	GW-2	9.31		2"
	base. <del>Down</del> at		16:51	GW-1	8.89		2"
15:00	Down DRS (under land		17:15	Pick up storm drain			
	indicator probe			grade adjacent to			
15:05	SW-5 WL	5.37	TOC	SW-1			
15:10	SW-3	7.97	6"	17:45	Can not locate storm		
15:15	DW-3	8.23	2"	drain grade on east			
	DW-1	8.12	1"	side			
	SW-2	7.18	2"	18:00	Left Site		
	SW-1	6.67	2"				
	SW-4	6.92	2"				
15:35	SW-7	5.76	2"				
15:42	DW-7	9.02	2"				
15:53	DW-6	7.18	2"				
	SW-10	6.57	2"				
	SW-9	7.18	2"				
	DW-5	6.98	2"				
16:15	DW-8	7.02	2"				
	SW-6	7.33					

May - 12 Green

DATE 1/20/93

JOB

DATE

CHIEF Forrest

PAGE 1

PARTY CHIEF

PAGE

8:00 Pat Hughes: I got a pass  
to get into base. Pass office  
opened at 8:00.

8:30 Set up on SW-9 and  
DW-6

9:00 SW-9 WL 6.68 TOL  
BOTH 34.90 TOL

9:10 DW-6  
WL 6.47 TOL  
BOTH 43.61 TOL

9:15 Canister A7 meter

9:25 Purity DW-5  
pH 6.74 7.39 7.57  
Cond 1743 1006 1498  
T(°F) 55.7 57.2 55.2

9:45 Purity 55 Gelling  
~~DW-5~~ SW-9

Pt 7.49 7.73 7.82  
Cond 1868 1501 1540  
Temp 56.3 60.1 57.7

10: Purity 70 Gelling

10:00 Sample ~~DW-9~~ DW-6

10:15 Sample ~~DW-9~~ SW-9

10:30 Decon Equipment

11:00 Set up on SW-10 and DW-6

11:10 Purity DW-6

7.33 WL TOL

44.66 BOTH TOL

pH 8.14 7.84 7.80

Cond 1741 1884 1874

T(°F) 60.2 61.7 62.0

11:30 Purity SW-10

6.75 WL TOL

SW-10

SW-10

Pt 8.02 7.84 7.90

Cond 1982 1910 1898

Temp(°F) 62.5 63.1 63.7

11:45 Sample DW-6 / Decon Brk  
 12:00 Sample SW-10  
 12:10 Decon Equipment  
 Purg'd 70 Gallons of water  
 from SW-10 and 55 Gallons  
 from DW-6  
 12:30 Purg'ing DW-7  
 WL 9.32 TOC  
 Bolt 47.30 TOC  
 pH 15.74 15.81 15.88  
 Cond 106.7 12.83 12.99  
 Temp (°F) 58.8 62.0 61.5  
 12:45 Sample DW-7  
 12:55 Decon Equipment  
 13:15 Purg'ing DW-8  
 WL 7.15 TOC  
 Bolt 3.2  
 pH 15.95 15.99  
 Cond 32.8 45.4  
 Temp (°F) 58.5 61.4  
 13:30 Sample DW-8  
 13:45 Decon Equipment

14:15 Purg'ing DW-4  
 WL - 8.44  
 Bolt - 63.88  
 pH 15.40 - 14.32 - 12.02  
 Cond 174.4 - 162.8 - 18.30  
 Temp (°F) 58.6 - 59.4 - 58.4  
 14:45 Sample DW-4  
 14:55 Decon Equip  
 15:10 Purg'ing DW-3  
 WL - 8.48 TOC  
 Bolt - 63.80 TOC  
 pH 7.01 - 7.33 - 7.24  
 Cond 180.4 - 169.2 - 158.6  
 Temp (°F) 53.2 - 57.7 - 52.8  
 15:45 Sample DW-3  
 15:55 Clean-up : Decon  
 16:10 Equipment Black Sample  
 16:20 Fuel Black Sample  
 collected  
 16:40 Call Office

REF

DATE 1/21/93

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PARTY

PAGE

8:00 Pat Hudis (ESE) and I get  
passes to enter Q-Block

9:00 Decon Equipment

9:30 Sample Sediment 2-



Drum		Inventory		Water
Well No		Soil		
DW-3	111		11	
DW-4	10		11	
DW-5	11		11	
DW-6	1		11	
DW-7	1		11	
DW-8	1		11	
SW-9	1		11	
SW-10	1		11	
N drop	11 m.v.		11	
DW-1			11	
SW-1			11	
DW-2			11	
SW-2			11	

## **Appendix D**

### **Boring Logs**

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: OSWL lca

BORING NO: SN-1

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 10/1/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S. Ulrich

NORTH: 1071430.32

\* EAST: 3693865.68

GROUND SURFACE ELEV: 3 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 6.67 feet TOC

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: N/A

GWL EQUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

[illegible]

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: DSH2.log BORING NO: SW-2 PROJECT NAME: 0 Area  
 DATE BEGAN: N/A DATE FINISHED: 10/1/90 FIELD GEOLOGIST: M. Scrobacz  
 DRILLER: S. Ulrich NORTH: 1971411.51 EAST: 3693850.52  
 GROUND SURFACE ELEV: 10.5 feet GWL DATE/TIME: 1/19/93 GWL DEPTH: 7.18 feet TOC  
 DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER DRILL EQUIP: N/A GWL EQUIP: ORS  
 CONTRACTOR: Hardin-Huber CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	PROFILE	DESCRIPTION	USCS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
	0.00	SS1	32-19	18		SILTY SAND: Yellowish brown Sand with silt; shell fragments; moist	SM	0		
	10.0	SS2	16-14	12				0		
	-5.00	SS3	8-8	14				0		
	-5.0	SS4	8-6	12				1.2		
	-10.00									
	-15.00	SS6	3-2	18		SILTY SAND: Black sand with silt; shell fragments; wet.	SM			
	-20.00	SS7	23-21	19						
	-25.00	SS8	3-3	24						

Bottom of hole • 25'

# BORING LOG SHEET

PROJECT NO: 4921150 FILE NO: CSH3 loc

BORING NO: SW-3

PAGE 1 OF 1

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 8/29/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S. Ulrich

NORTH: 1071347.46

EAST: 3693861.38

GROUND SURFACE ELEV: 13.5 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 7.97 feet TOC

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: N/A

GWL EQUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	PROFILE	DESCRIPTION	USCS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
0.00		SS1	2-2	4		SILTY SAND: Yellow-brown Sand with silt; shell fragments; moist	SM	0		
		SS2	8-10	13						
10.0										
		SS3	11-12	18						
-5.00						SAND: Grey sand; wet.	SP			
		SS4	9-12	18						
		SS5	7-6	16						
5.0										
-10.00										
		SS6	3-2	18						
-15.00										
5.0										
-20.00										
		SS7	16-17	18						
10.0										
-25.00		SS8	3-2	18						

Bottom of hole • 25'

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: OSW4 log

BORING NO: SW-4

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 8/26/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S. Ulrich

NORTH: 1071283.66

EAST: 3693807.66

GROUND SURFACE ELEV: 12.0 feet

GWL DATE/TIME: 8/19/90

GWL DEPTH: 6.92 feet TOC


DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: N/A

GWL EQUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	P R O F I L E	DESCRIPTION	U S C S	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
	0.00	SS1	7-7	8		SILTY SAND: Yellow-brown Sand with silt; shell fragments; moist.	SM	0		
10.0										
		SS2	11-12	19						
-5.00		SS3	8-10	13						
-3.0		SS4	9-11	18						
		SS5	6-9	18						
-10.00										
		SS6	3-3	18						
-15.00										
5.0										
-20.00										
10.0		SS7	3-3	18						

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: OSW5 log

BORING NO: BW-5

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 9/25/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S. Ulrich

NORTH: 1071253.30

EAST: 3693890.65

GROUND SURFACE ELEV: 10.5 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 5.37 feet TOC

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: N/A

GWL EQUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	PROFILE	DESCRIPTION	USCS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
10.0	0.00	SS1	12-13	14		SILTY SAND: Yellow-brown Sand with silt, shell fragments; moist	SM	0		
								2		
		SS2	12-19	11						
								0		
		SS3	11-13	18						
		SS4	7-8	18						

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: 05W6.log

BORING NO: SW-6

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 9/28/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S. Ulrich

NORTH: 1071344 78

EAST: 3693788.00

GROUND SURFACE ELEV: 12.7 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 7.33 feet TOC

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: N/A

GWL EQUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	PROFILE	DESCRIPTION	USCS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
	0.00	SS1	5-6	13		SILTY SAND: Yellow-brown Sand with silt; shell fragments; moist.	SM	0		
	10.0	SS2	13-16	6						
	5.00	SS3	10-8	18						
	10.0	SS4	7-6	18						
	15.0	SS5	3-3	18						
	20.0	SS6	5-5	18		SAND: Black sand; wet.	SP			
	25.00	SS7	1-1	18						Bottom of hole • 25'



# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: CSW7 loc

BORING NO: 34-7

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 10/1/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S. Ulrich

NORTH: 1071222.56

EAST: 3693771.24

GROUND SURFACE ELEV: 11.2 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 5.76 feet TOC

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: N/A

GWL EDUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	PROBING	DESCRIPTION	USCS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
0.00		SS1	22-15	14		SILTY SAND: Yellow-brown Sand with silt; shell fragments; moist	SM	0		
-10.0										
		SS2	7-6	16						
-5.00		SS3	1-1	16						
		SS4	2-3	0						
-10.00										
-15.00		SS5	1-2	18						
5.0										
-20.00		SS6	6-5	18						
10.0										
-25.00		SS7	2-2	18						Bottom of hole • 25'

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: CSW8 100

BORING NO: SW-8

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 10/1/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S. Ulrich

NORTH: 1071480 32

EAST: 3693914.74

GROUND SURFACE ELEV: 13.0 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 7.38 feet TOC

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: N/A

GWL EQUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	PROFILE	DESCRIPTION	USCS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
0.00		SS1	15-38	18		SILTY SAND: Yellow-brown Sand with silt, shell fragments; moist	SM			
10.0		SS2	18-13	18						
5.00		SS3	9-6	18						
5.0		SS4	2-3	18						
10.00										
0.0						SAND: Black sand; wet.				
15.00		SS5	1-3	18		CLAY: Black clay; organic; plastic; wet.	SP CH			
						SAND: Black sand; wet.	SP	0		
5.0										
20.00		SS6	1-1	18		SILT: Black silt; organic; plastic; wet.	ML	220		
10.0						SAND: Black sand; wet.	SP			
5.00		SS7	2-3	18		CLAY: Grey and blue-green clay; organic; plastic.	CH	10		Bottom of hole • 25'

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: 00W5.100

BORING NO: 24-9

PROJECT NAME: Q Area

TE BEGAN: 1/6/92

DATE FINISHED: 1/5/93

FIELD GEOLOGIST: A. Forrest

WILLER: 0 Queen

NORTH: 1071746 20

EAST: 3693547.26

GROUND SURFACE ELEV: 3.5 Feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 7 18 Feet TOC

DRILLING METHOD: 4-1/2" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

GWL EQUIP: ORS

**CONTRACTOR:** Groundwater Systems, Inc

CHECKED BY: N/A

[illegible]

# BORING LOG SHEET

PROJECT NO: 4921150 FILE NO: QSW10 100

TE BEGAN: 1/7/92

BORING NO: SW-10

DATE FINISHED: 1/7/93

PAGE 1 OF 1

PROJECT NAME: Q Area

FIELD GEOLOGIST: A. Forrest

EAST : 3693497.91

GROUND SURFACE ELEV: 8.5 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 6.57 Feet TOC

DRILLING METHOD: 4-1/2" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

GWL EQUIP: ORS

CONTRACTOR: Groundwater Systems, Inc

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER 10.5'	REC (FT)	BOREHOLE	DESCRIPTION	LOGS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
10.0	0.00					ASPHALT/BASE ROCK.				0.3 Feet of Base stone
						SAND: Reddish brown sand with shell fragments, trace gravel; fine to coarse grained, sub-angular, unsorted, wet, medium dense.	SP	0	0	Samples were collected using CME's 5-foot continuous sampler
	-5.00									Moist
								0	0	
	-10.00					SHELLY SAND: Olive-brown sand trace gravel; fine to coarse, sub-angular, unsorted, wet, loose.				
								0	0	
	-15.00									
								0	0	
	-20.00						SP			
								0	0	
	-25.00									
								0	0	
	-30.00					SAND: Brown gray sand and shell fragments; fine to coarse, subangular, unsorted; wet, medium dense.	SP			
						CLAYEY SILT: Light gray silt with clay slightly plastic, wet, medium dense.	ML			
	-35.00					SAND: Brown gray sand; fine to coarse, subangular, unsorted; wet, medium dense.	SP			Bottom of Hole
						BOTTOM OF BORING AT 35.0'				

# BORING LOG SHEET

PROJECT NO: 4921150 FILE NO: C3WL100

DATE BEGAN: N/A

ALLER: S. Ulrich

GROUND SURFACE ELEV: 12.7 Feet

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

**CONTRACTOR:** Hardin-Huber

BORING NO: CW-1

DATE FINISHED: 10/2/90

NORTH: 1071413 61

GWL DATE/TIME: 1/19/93

DRILL EQUIP: N/A

PAGE 1 OF 1

PROJECT NAME: Q Area

FIELD GEOLOGIST: M. Scrobacz

EAST: 3693848.06

GWL DEPTH: 8.12 Feet TOC

GWL EQUIP: ORS

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	METHOD	DESCRIPTION	SOXHC	VOLATILE ORGANIC VAPORS (ppm)	REMARKS
								FID PID	
	0.00					SILTY SAND: Yellow-brown Sand with silt; shell fragments; moist.			0.3 Feet of Base stone
		G81	21-18	14			6H		
10.0		G82	10-6	14					
-5.00		G83	8-8	18					
		G84	7-7	18					
-10.00		G85	5-3	18				0	
-15.00		G86	1-1	18		SILTY SAND: Black sand with silt; wet.	6P	18	
-20.00		G87	2-3	18				10	Brown clay lens (19.7' - 20")
		G88	7-8	18				30	
-25.00		G89	4-5			SILTY SAND: Yellow-brown sand with silt; wet.	6M	98	
		G810	5-4			SAND: Black sand; with some silt and gravel; wet	6M	110	
-30.00		G811	3-2					120	Dark brown clay lens (27.7' - 27.9')
		G812	3-6	24				10	Dark brown clay lens (29.3' - 29.5')
-35.00		G813	8-7			SILTY SAND: Yellow-brown sand with silt; shell fragments.	6H	80	
		G814	6-10					0	
-40.00		G815	3-6			SAND: Orange sand with silt; shell fragments; wet.	6M		Black staining (39.0'
		G816	3-4						
-45.00		G817	8-9						
		G818	13-14						
-50.00		G819	14-11						Bottom of hole @ 45'

# BORING LOG SHEET

PROJECT NO: N/A FILE NO: 0042.log

BORING NO: DW-2

PAGE 1 OF 1

PROJECT NAME: 0 Area

DATE BEGAN: N/A

DATE FINISHED: 9/27/90

FIELD GEOLOGIST: M. Scrobacz

DRILLER: S Ulrich

NORTH: 1071481.84

EAST: 3693912.54

GROUND SURFACE ELEV: 12.9 Feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 8.41 Feet TOC

DRILLING METHOD: 6-1/4" ID HSA

DRILL EQUIP: N/A

GWL EQUIP: ORS

CONTRACTOR: Hardin-Huber

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	CORRECTION	DESCRIPTION	C	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
0.00		GS1	3-3	11		SILTY SAND: Yellow-brown Sand with silt; shell fragments; wet.	SP	0.9		Asphalt and base stone (0.2')
		GS2	6-7	18				0		
10.0		GS3	10-11	18						
-5.00		GS4	7-6	14				1.5		
5.0		GS5	5-4	12						
-10.00										
0.0		GS6	3-2	10				0.6		
-15.00						SAND: Black sand; wet.	SP			
5.0		GS7	5-5	19				58		Strong odor @ 13'
-20.00		GS8	1-1							Thin clayey silt lens (21.3' - 21.5')
10.0										
-25.00		GS9	9-6			SILTY SAND: Brown sand with silt; wet.	SP			
15.0		GS10	8-13			SAND: Brown sand with gravel; shell fragments; wet.	SP- SP			
-30.00		GS11	7-9			SILTY SAND: Dark brown sand with silt; shell fragments; wet.	SP			
20.0		GS12	8-9							
-35.00		GS13	10-11							
25.0		GS14	10-11			SAND: Black and white sand; shell fragments; wet.	SP			
-40.00		GS15	13-11			SILTY SAND: Yellow-brown sand with silt; shell fragments; wet.	SP			
30.0		GS16	13-13					0.8		
		GS17	8-9					0		
		GS18	11-12							
-6.00						Bottom of hole @ 45'				

# BORING LOG SHEET

PAGE 1 OF 2

PROJECT NO: 4921150 FILE NO: QOW3.10a

BORING NO: CH-3

PROJECT NAME: 0 Area

E BEGAN: 12/14/92

DATE FINISHED: 12/15/92

FIELD GEOLOGIST: A. Forrest

ALLER: D. Queen

NORTH: 2071413.61

EAST: 3693848.06

GROUND SURFACE ELEV: 12.6 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 8.23 feet TOC

DRILLING METHOD: 4-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

GWL EQUIP: DRS

CONTRACTOR: Groundwater Systems, Inc

CHECKED BY: N/A

[illegible]

# BORING LOG SHEET

PROJECT NO: 4921150 FILE NO: 00W3A.100

BORING NO: OH-3

PAGE 2 OF 2

PROJECT NAME: 0 Area

E BEGAN: 12/14/92

DATE FINISHED: 12/15/92

FIELD GEOLOGIST: A. Forrest

WILLER: O. Queen

NORTH: 1071413.61

EAST: 3693848.06

GROUND SURFACE ELEV: 12.6 Feet

GWL DATE/TIME: 1/19/93

**GWL DEPTH:** 8.23 Feet TOC

DRILLING METHOD: 4-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

GWL EQUIP: ORS

CONTRACTOR: Groundwater Systems, Inc

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	CORRECTION	DESCRIPTION	CLOG	VOLATILE ORGANIC VAPORS (ppm)		REMARKS		
								FID	PID			
-10.00						SHELLY SAND: Light Brown sand with shell fragments; fine to coarse, subrounded, unsorted, wet, loose.	SP			Samples were collected using CME's 5-foot continuous sampler		
30.0												
-45.00												
35.0												
		691		1.1							0	0
-50.00												
40.0											0	0
		982		1.3								
-55.00												
45.0											0	0
		983		1.7								
-60.00												
50.0								0	0			
		984		1.9								
-65.00	BOTTOM OF BORING AT 65.0'									BOTTOM OF HOLE = 65'		
55.0												
-70.00												
60.0												
-75.00												
65.0												
-80.00												



# BORING LOG SHEET

PAGE 1 OF 2

PROJECT NO: 4921150 FILE NO: 00W4 100

BORING NO: BW-4

PROJECT NAME: 0 Area

DATE BEGAN: 12/15/92

DATE FINISHED: 12/15/92

FIELD GEOLOGIST: A. Forrest

DRILLER: D. Queen

NORTH: 1071483 33

EAST: 3693906.79

GROUND SURFACE ELEV: 12.8 Feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 8.12 Feet TOC

DRILLING METHOD: 4-1/4" ID HSA

DRILL EQUIP: Acker

GWL EQUIP: QRS

CONTRACTOR: Groundwater Systems, Inc

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	CORRECTION (FT)	DESCRIPTION	LOGS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
0.00						SILTY SAND: Yellow-brown Sand with silt; shell fragments; wet.	SH			
10.0										
-5.00										
-10.00										
-15.00						SAND: Black sand; wet.	SP			
-20.00										
-25.00						SILTY SAND: Brown sand with silt; wet.	SH			
-30.00						SAND: Brown sand with gravel; shell fragments; wet.	GP-SP			
-35.00						SILTY SAND: Dark brown sand with silt; shell fragments; wet.	SH			
-40.00						SAND: Black and white sand; shell fragments; wet.	SP			
-45.00						SHELLY SAND: Yellow-brown sand with shell fragments; fine to medium, unsorted, wet, loose.	SP			

# BORING LOG SHEET

PAGE 2 OF 2

PROJECT NO: 4921150 FILE NO: 00W4 100

BORING NO: OW-4

PROJECT NAME: Q Area

E BEGAN: 12/15/92

DATE FINISHED: 12/15/92

FIELD GEOLOGIST: A. Forrest

ALLER: O. Queen

NORTH: 1071483.33

EAST: 3693906.79

GROUND SURFACE ELEV: 12.8 Feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 8.12 Feet TOC

DRILLING METHOD: 4-1/4" ID HSA

DRILL EQUIP: Acker

GWL EQUIP: ORS

CONTRACTOR: Groundwater Systems, Inc.

CHECKED BY: N/A

[illegible]

# BORING LOG SHEET

PAGE 1 OF 1

PROJECT NO: 4921150 FILE NO: 00W5 100

BORING NO: 24-5

PROJECT NAME: D Area

DATE BEGAN: 1/5/92

DATE FINISHED: 1/5/93

FIELD GEOLOGIST: A Forrest

LLER: D. Queen

NORTH: 1071745 49

EAST: 3693544.86

GROUND SURFACE ELEV: 11.7 Feet

GWL DATE/TIME: 2/19/93

BWL DEPTH: 6.98 feet TOC

DRILLING METHOD: 6-1/4" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

GWL EQUIP: ORS

CONTRACTOR: Groundwater Systems, Inc.

CHECKED BY: N/A

[illegible]

# BORING LOG SHEET

PROJECT NO: 4921150 FILE NO: 0046.100

BORING NO: CH-6

PAGE 1 OF 1

PROJECT NAME: Q Area

DATE BEGAN: 1/6/92

DATE FINISHED 1/6/93

FIELD GEOLOGIST: A. Forrest

ILLER: O. Queen

NORTH: 1071439.00

EAST: 3693498.18

GROUND SURFACE ELEV: 10.6 Feet

GWL DATE/TIME: 1/19/93

BWL DEPTH: 6.98 Feet TOC

DRILLING METHOD: 4-1/2" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

GWL EQUIP: ORS

**CONTRACTOR:** Groundwater Systems, Inc

CHECKED BY: N/A

[illegible]

# BORING LOG SHEET

PAGE 1 OF 2

PROJECT NO: 4921150 FILE NO: COW7 100 BORING NO: CW-7 PROJECT NAME: 0 Area  
 DATE BEGAN: 1/8/92 DATE FINISHED: 1/8/93 FIELD GEOLOGIST: A. Forrest  
 DRILLER: D. Queen NORTH: 1071353 11 EAST: 3693572.21  
 GROUND SURFACE ELEV: 13.0 Feet GWL DATE/TIME: 1/19/93 GWL DEPTH: 9.02 feet TOC  
 DRILLING METHOD: 4-1/2" ID HOLLOW-STEM AUGER DRILL EQUIP: Acker GWL EQUIP: OAS  
 CONTRACTOR: Groundwater Systems, Inc. CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	METHOD	DESCRIPTION	USCS	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
0.00						ASPHALT/BASE ROCK.				
10.0		S1	3.1			SHELLY SAND: Light brown sand with shell fragments, trace gravel; fine to coarse grained, sub-angular, unsorted, moist, medium dense.	SP	0	0	0.3 feet of Base stone Samples were collected using CME's 5-foot continuous sampler
-5.00										
5.0		S2	3.6					0	0	Moist
-10.00						SAND: Olive-brown sand trace gravel; fine to coarse, sub-angular, unsorted, wet, loose.				
0.0		S3	1.7				SP	0	0	
-15.00										
5.0		S4	1.1					0	0	
-20.00										
10.0		S5	1.2					0	0	
-25.00							SP			

## BORING LOG SHEET

PAGE 2 OF 2

JECT NO: 4921150 FILE NO: 00W7a.10a

BORING NO: CH-7

PROJECT NAME: 0 Area

DATE BEGAN: 1/8/92

DATE FINISHED: 1/8/93

FIELD GEOLOGIST: A. Forrest

DRILLER: O. Queen

NORTH: 1071353.11

EAST: 3693572.21

GROUND SURFACE ELEV: 13.0 feet

GWL DATE/TIME: 1/19/93

GWL DEPTH: 9.02 feet TOC





DRILLING METHOD: 4-1/2" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

GWL EQUIP: ORS

CONTRACTOR: Groundwater Systems, Inc.

CHECKED BY: N/A

ELEV (FT)	DEPTH (FT)	SAMPLE TYPE AND NO	SPT BLOWS PER (0.5')	REC (FT)	P R O F I L E	DESCRIPTION	U S C S	VOLATILE ORGANIC VAPORS (ppm)		REMARKS
								FID	PID	
	-25.00					SAND: Olive-brown sand trace gravel.	SP			Samples were collected using CME's 5-foot continuous sampler
						GRAVELLY SAND: Brown gray sand and gravel; fine to coarse, subangular, unsorted; wet, dense.	SP/GR	0	0	
15.0		S6		5.0		SAND: Olive-brown sand trace gravel; fine to coarse, sub-angled, unsorted, wet, loose.	SP			
						GRAVELLY SAND: Brown gray sand and gravel; fine to coarse, subangular, unsorted; wet, dense.	SP/GR			
-30.00						SAND: Olive-brown sand trace gravel; fine to coarse, sub-angled, unsorted, wet, loose.	SP	0	0	
		S7		4.1		GRAVELLY SAND: Brown gray sand and gravel; fine to coarse, subangular, unsorted; wet, dense.	SP/GR			
20.0						SAND: Olive-brown sand trace gravel; fine to coarse, sub-angled, unsorted, wet, loose.	SP	0	0	
						GRAVELLY SAND: Brown gray sand and gravel; fine to coarse, subangular, unsorted; wet, dense.	SP/GR			
-35.00						SAND: Olive-brown sand trace gravel; fine to coarse, sub-angled, unsorted, wet, loose.	SP	0	0	
25.0		S8		4.5						
-40.00										
		S9		4.5				0	0	
30.0										
-45.00										
		S10		4.5				0	0	
40.0										
						SHELLY SAND: Gray sand and shell fragments; fine to coarse, subangular, unsorted; wet, medium dense.	SP			Bottom of Hole @ 50'
-50.00										

# BORING LOG SHEET

PROJECT NO: 4921150 FILE NO: DDW8.10q

DATE BEGAN: 1/8/92

ILLER: 0 Queen

BORING NO: CW-8

DATE FINISHED: 1/8/93

NORTH: 1071714 60

GROUND SURFACE ELEV: 12.3 Feet

GWL DATE/TIME: 2/19/93

DRILLING METHOD: 4-1/2" ID HOLLOW-STEM AUGER

DRILL EQUIP: Acker

**CONTRACTOR:** Groundwater Systems, Inc

PAGE 1 OF 1

PROJECT NAME: 0 Area

FIELD GEOLOGIST: A. Forrest

EAST: 3693685.11

6WL DEPTH: 7.02 Feet TOC

GWL EQUIP: ORS

CHECKED BY: N/A

[illegible]

# BORING LOG

[illegible]

**Note: Slightly stained area with fuel odor. Near previous location of damaged drums**



# BORING LOG

[illegible]

## BORING LOG

CLIENT: Navy (LANTNAVFACENGCOM) LOCATION: Norfolk Naval Base Q-Area (Haz. Mat. Area)		SOIL BORING #: HM-3 TOTAL DEPTH: 3 feet LOGGED BY: M. Skrobacz DRILLER: N/A DRILL RIG: N/A METHOD: Hand Auger DATE DRILLED: 10/3/90	
WELL CONSTRUCTION: N/A			

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-0.3		Base stone	
0.3-1.2	SM	Black moist SAND with silt and gravel	
1.2-3.0	SM	Yellow brown moist SAND with silt	
		Limit of boring @ 3 feet	

Note: Heavily stained. Shell frags.

# BORING LOG

CLIENT: Navy (LANTNAVFACENGCOM)		SOIL BORING #: HM-4
LOCATION: Norfolk Naval Base Q-Area (Haz. Mat. Area)		TOTAL DEPTH: 3 feet
		LOGGED BY: CWB
WELL CONSTRUCTION: N/A		DRILLER: N/A
		DRILL RIG: N/A
		METHOD: Hand Auger
		DATE DRILLED: 10/3/90

DEPTH (in.)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-7		Base stone	0
7-18	SM	Yellow-brown to dark brown moist with silt and some shell frags. Heavy staining and odor  Sample No. HM-4-1	0
18-36	CL	Same as above with few yellow-brown sandy clay  Sample No. HM-4-2 and HM-4-2 FD	0 0
		End boring @ 3 feet	

Note: Between drums of dry cleaning solvent and fence, heavily stained. Diesel/fuel odor

# BORING LOG

[illegible]

# BORING LOG

[illegible]

# BORING LOG

[illegible]

# BORING LOG

[illegible]

# BORING LOG

[illegible]



# BORING LOG

CLIENT: Navy (LANTNAVFACENGCOM) LOCATION: Norfolk Naval Base Q-Area (Haz. Mat. Area)		SOIL BORING #: HM-10 TOTAL DEPTH: 3 feet LOGGED BY: CWB DRILLER: N/A DRILL RIG: N/A METHOD: Hand Auger DATE DRILLED: 10/4/90	
WELL CONSTRUCTION: N/A			
DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-5	SM	Base stone	0
5-18	SM	Yellow-brown moist sand with silt and shell frags. Few cobbles, some gravel  Sample No. HM-10-1	0
18-36	SM/CL	Same as above with few yellow-brown sandy clay clasts  Sample No. HM-10-2	0 0
		End of boring @ 3 feet	

Note: Note to cement footing. No staining or odor

# BORING LOG

[illegible]

# **BORING LOG**

<b>CLIENT:</b>	Navy (LANTNAVFACENGCOM)
<b>LOCATION:</b>	Norfolk Naval Base Q-Area (Petroleum Products Area)
<b>WELL CONSTRUCTION:</b>	N/A
<b>SOIL BORING #:</b>	PP-2
<b>TOTAL DEPTH:</b>	3 feet
<b>LOGGED BY:</b>	CWB
<b>DRILLER:</b>	N/A
<b>DRILL RIG:</b>	N/A
<b>METHOD:</b>	Hand Auger
<b>DATE DRILLED:</b>	9/27/90

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-5		Base stone	
5-18	SM	Yellow-brown moist sand with silt and shell fragments  Sample No. PP-2-1	0
18-36	SM	Same as above  Sample No. PP-2-2	0
		End of boring @ 3 feet	

Note: Center of aisle between footings. No visible staining or odor. Had to offset 3 times. Hit cement or something @ 4' in orig. hole and 1st two offsets. Moved next to cement footing for third offset. No visible staining, no odor

# BORING LOG

[illegible]

# BORING LOG

[illegible]

# BORING LOG

[illegible]

# BORING LOG

CLIENT: Navy (LANTNAVFACENGCOM) LOCATION: Norfolk Naval Base Q-Area (Petroleum Products Area)		SOIL BORING #: PP-6 TOTAL DEPTH: 3 feet LOGGED BY: CWB DRILLER: N/A DRILL RIG: N/A METHOD: Hand Auger DATE DRILLED: 9/26/90	
WELL CONSTRUCTION: N/A			
DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-3		Base stone	
3-18	SM	Yellow-brown moist sand with silt and some shell fragments  Sample No. PP-6-1	
18-36	SM	Same as above  Sample No. PP-6-2	
		End of boring @ 3 feet	

Note: Next to cement footing. Slightly stained slightly petroleum odor

## BORING LOG

[illegible]



# BORING LOG

<b>CLIENT:</b>	Navy (LANTNAVFACENGCOM)
<b>LOCATION:</b>	Norfolk Naval Base Q-Area (Petroleum Products Area)
<b>WELL CONSTRUCTION:</b>	N/A
<b>SOIL BORING #:</b>	PP-8
<b>TOTAL DEPTH:</b>	3 feet
<b>LOGGED BY:</b>	CWB
<b>DRILLER:</b>	N/A
<b>DRILL RIG:</b>	N/A
<b>METHOD:</b>	Hand Auger
<b>DATE DRILLED:</b>	10/1/90

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-4		Base stone	0
4-18	SM	Yellow-brown moist sand with silt and shell fragments  Sample No. PP-8-1	0
	CL	Sandy gray-green clay 1" thick @ 10"	0
18-36	SM	Yellow-brown moist sand with silt and shell fragments  Sample No. PP-8-2	
		End of boring @ 3 feet	

Note: Next to cement footing. Slightly stained. No odor

# BORING LOG

<b>CLIENT:</b> Navy (LANTNAVFACENGCOM) <b>LOCATION:</b> Norfolk Naval Base Q-Area (Petroleum Products Area)		<b>SOIL BORING #:</b> PP-9 <b>TOTAL DEPTH:</b> 3 feet <b>LOGGED BY:</b> CWB <b>DRILLER:</b> N/A <b>DRILL RIG:</b> N/A <b>METHOD:</b> Hand Auger <b>DATE DRILLED:</b> 10/2/90	
<b>WELL CONSTRUCTION:</b> N/A			

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-3		Base stone	0
3-18	SM	Yellow-brown moist sand with silt and shell fragments and coquina.	
	CL-CH	Light gray and yellow brown sandy clay @ 13" Sample No. PP-9-1	
18-31		Same as above Sample No. PP-9-2	
32-36	CH	Light gray clay	
		End of boring @ 3 feet	

Note: Middle of aisle. No visible staining; no odor. Offset 1' - hit rock @ 12-inch

# BORING LOG

[illegible]

# BORING LOG

CLIENT: Navy (LANTNAVFACENGCOM) LOCATION: Norfolk Naval Base Q-Area (Petroleum Products Area)		SOIL BORING #: PP-11 TOTAL DEPTH: 3 feet LOGGED BY: CWB DRILLER: N/A DRILL RIG: N/A METHOD: Hand Auger DATE DRILLED: 9/26/90	
WELL CONSTRUCTION: N/A			

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-0.2		Base stone	
2-18	SM	Grey becoming yellow brown moist sand with silt and some shell fragments  Sample No. PP-11-1	
18-36	SM	Same as above  Sample No. PP-11-2	
		End of boring @ 3 feet	

Note: Next to cement footing. Highly stained area

# BORING LOG

[illegible]

# **BORING LOG**

CLIENT: Navy (LANTNAVFACENGCOM)		SOIL BORING #: PP-13	
LOCATION: Norfolk Naval Base		TOTAL DEPTH: 3 feet	
Q-Area (Petroleum Products Area)		LOGGED BY: CWB	
		DRILLER: N/A	
		DRILL RIG: N/A	
		METHOD: Hand Auger	
		DATE DRILLED: 10/1/90	
WELL CONSTRUCTION: N/A			
DEPTH (in.)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-5		Base stone	0
5-36	SM CH	Yellow-brown moist sand with silt and shell fragments Wet clay, yellow brown @ 30-inch (1/2-inch thick) woodchips	0 0
		End of boring @ 3 feet	

Note: Center of aisle. No visible staining, no odor

# BORING LOG

[illegible]

# BORING LOG

<b>CLIENT:</b>	Navy (LANTNAVFACENGCOM)
<b>LOCATION:</b>	Norfolk Naval Base Q-Area (Transit Area)
<b>WELL CONSTRUCTION:</b>	N/A
<b>SOIL BORING #:</b>	TA-1
<b>TOTAL DEPTH:</b>	3 feet
<b>LOGGED BY:</b>	MES
<b>DRILLER:</b>	N/A
<b>DRILL RIG:</b>	N/A
<b>METHOD:</b>	Split-spoon
<b>DATE DRILLED:</b>	9/25/90

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-0.3	SM	Base stone	0
0.3-3.0	SM	Yellow-brown moist SAND with SILT	0
		End of boring @ 3 feet	

Note: Stained. 11" recover. 11" recover.



# BORING LOG

[illegible]

# BORING LOG

[illegible]

# BORING LOG

<b>CLIENT:</b>	Navy (LANTNAVFACENGCOM)
<b>LOCATION:</b>	Norfolk Naval Base Q-Area (Transit Area)
<b>WELL CONSTRUCTION:</b>	N/A
<b>SOIL BORING #:</b>	TA-4
<b>TOTAL DEPTH:</b>	3 feet
<b>LOGGED BY:</b>	MES
<b>DRILLER:</b>	N/A
<b>DRILL RIG:</b>	N/A
<b>METHOD:</b>	Split-spoon
<b>DATE DRILLED:</b>	9/25/90

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0.3		Base stone	0
3.0	SM	Yellow brown moist SAND with silt	0
		End of boring @ 3 feet	

Note: No stain. Middle of transit arid.

# BORING LOG

CLIENT: Navy (LANTNAVFACENGCOM) LOCATION: Norfolk Naval Base Q-Area (Transit Area)		SOIL BORING #: TA-5 TOTAL DEPTH: 3 feet LOGGED BY: MES DRILLER: N/A DRILL RIG: N/A METHOD: Split-spoon DATE DRILLED: 9/25/90	
WELL CONSTRUCTION: N/A			
DEPTH (in.)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-0.2		Base stone	0
3.0	SM	Yellow-brown moist SAND with silt. Staining	1
		End of boring @ 3 feet	

Note: Redrilled for additional material. Offset 6".

# BORING LOG

[illegible]

## BORING LOG

<b>CLIENT:</b> Navy (LANTNAVFACENGCOM) <b>LOCATION:</b> Norfolk Naval Base Q-Area (Equipment Yard)		<b>SOIL BORING #:</b> EY-2 <b>TOTAL DEPTH:</b> 3 feet <b>LOGGED BY:</b> CWB <b>DRILLER:</b> N/A <b>DRILL RIG:</b> N/A <b>METHOD:</b> Hand Auger <b>DATE DRILLED:</b> 10/2/90	
<b>WELL CONSTRUCTION:</b> N/A			

DEPTH (In)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-6		Base stone	0
6-18	SM CL	Yellow-brown moist sand with silt and shell fragments. Light gray sandy clay clasts. Coquina clasts  Sample No. EY-2-1	0 10
18-36		Same as above (___ diesel ? odor)  Sample No. EY-2-2	0 80 50
		End of boring @ 3 feet	

Note: About 15' from Q-Area Drum Storage fence. No staining, no odor

## BORING LOG

<b>CLIENT:</b> Navy (LANTNAVFACENGCOM)		<b>SOIL BORING #:</b>	EY-3
<b>LOCATION:</b> Norfolk Naval Base		<b>TOTAL DEPTH:</b>	3 feet
<b>Q-Area (Equipment Yard)</b>		<b>LOGGED BY:</b>	CWB
		<b>DRILLER:</b>	N/A
		<b>DRILL RIG:</b>	N/A
		<b>METHOD:</b>	Hand Auger
<b>WELL CONSTRUCTION:</b> N/A		<b>DATE DRILLED:</b>	10/2/90

DEPTH (in.)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm) =
0-3		Base stone	0
3-18		Yellow-brown moist sand	0
18-36			0
		End of boring	

Note: About 15' from fence to drum storage yard

# BORING LOG

[illegible]



# BORING LOG

<b>CLIENT:</b>	Navy (LANTNAVFACENGCOM)
<b>LOCATION:</b>	Norfolk Naval Base Q-Area (Equipment Yard)
<b>WELL CONSTRUCTION:</b>	N/A
<b>SOIL BORING #:</b>	EY-5
<b>TOTAL DEPTH:</b>	3 feet
<b>LOGGED BY:</b>	CWB
<b>DRILLER:</b>	N/A
<b>DRILL RIG:</b>	N/A
<b>METHOD:</b>	Hand Auger
<b>DATE DRILLED:</b>	10/3/90

DEPTH (in)	CLASSIFICATION	LITHOLOGICAL DESCRIPTION	OVA (ppm)
0-6.5		Base stone	0
6.5-18	SM	Yellow-brown moist sand with silt and shell fragments. Few coquina clasts  Sample No. EY-5-1	0
18-36		Same as above with few ironstone clasts  Sample No. EY-5-2 and EY-5-2 FD	0
		End of boring @ 3 feet	

Note: Between cement footings about 25' from parking lot fence (slightly north of orig. location)

# BORING LOG

[illegible]

# BORING LOG

[illegible]

## **Appendix E**

### **Liquid Level Data for Monitor Wells**

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet-msl)	Rim Elevation (feet-msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet-msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet-msl)	Rim Elevation (feet-msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet-msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
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Monitor Well Number	Date	Ground Elevation (feet-msl)	Rim Elevation (feet-msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet-msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
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SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21



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Q Drum Storage Area  
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SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
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SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
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SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet-msl)	Rim Elevation (feet-msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet-msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet - msl)	Rim Elevation (feet - msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet - msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet - msl)	Rim Elevation (feet - msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet - msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet-msl)	Rim Elevation (feet-msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet-msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet - msl)	Rim Elevation (feet - msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet - msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21



Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet - msl)	Rim Elevation (feet - msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet - msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet-msl)	Rim Elevation (feet-msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet-msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

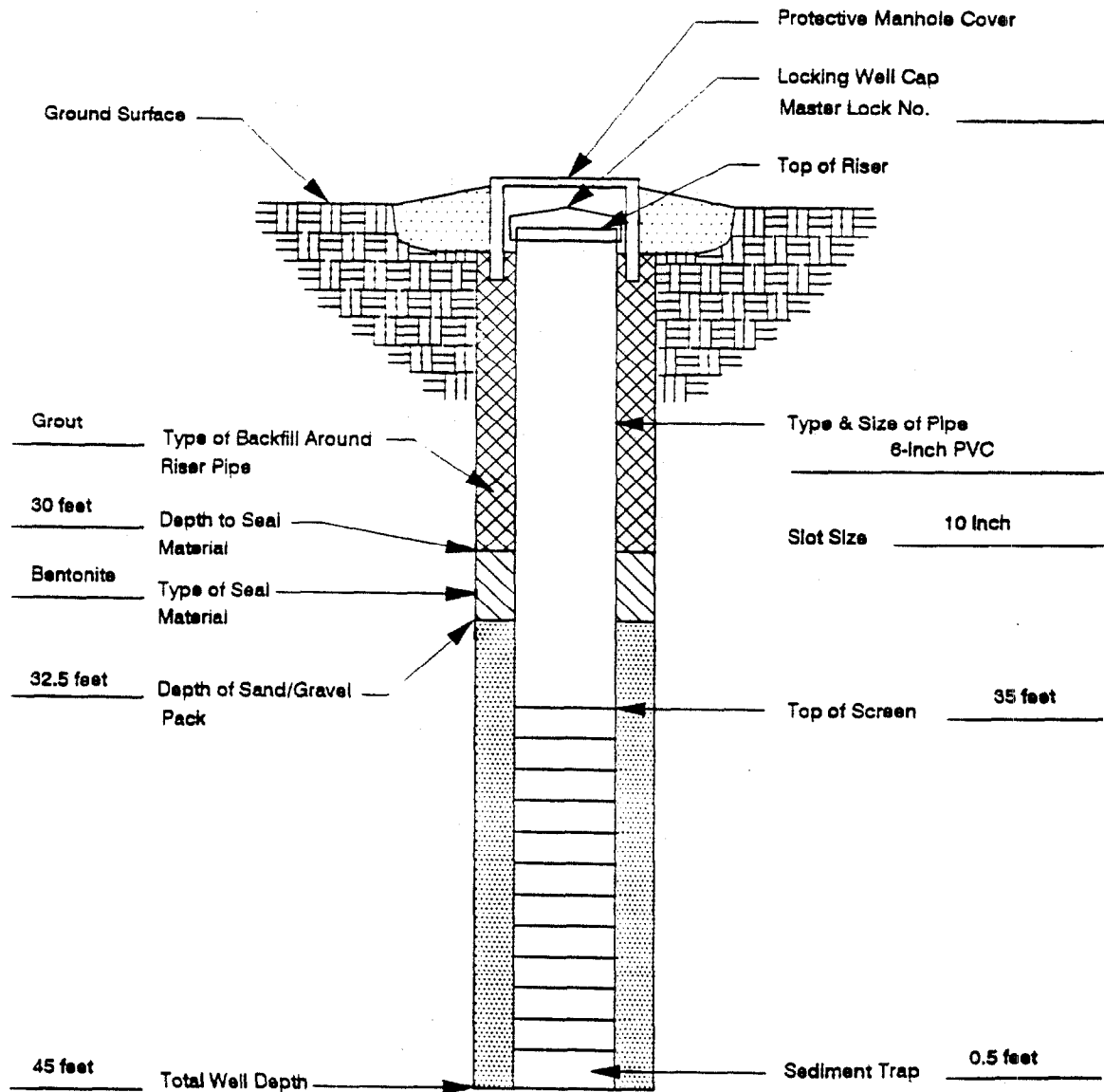
Environmental Science & Engineering

Q Drum Storage Area  
Norfolk Naval Base  
Norfolk, Virginia  
Monitor Well Data Table

Monitor Well Number	Date	Ground Elevation (feet-msl)	Rim Elevation (feet-msl)	East (feet)	North (feet)	Screen Interval (feet)	Depth to Bottom (feet)	Depth to Water (feet)	Groundwater Elevation (feet-msl)
SW-1	19-Jan-93	9.4	8.90	3693865.68	1071430.32	10-25	25	6.67	2.23
SW-2	19-Jan-93	9.7	9.35	3693850.52	1071411.51	10-25	25	7.18	2.17
SW-3	19-Jan-93	10.5	10.09	3693861.38	1071347.46	5-25	25	7.97	2.12
SW-4	19-Jan-93	9.0	8.82	3693807.66	1071283.66	10-25	25	6.92	1.90
SW-5	19-Jan-93	7.5	7.44	3693890.65	1071253.30	10-25	25	5.37	2.07
SW-6	19-Jan-93	9.7	9.16	3693498.18	1071344.78	10-25	25	7.33	1.83
SW-7	19-Jan-93	8.2	7.55	3693771.24	1071222.56	10-25	25	5.76	1.79
SW-8	19-Jan-93	10.0	9.59	3693914.73	1071480.32	10-25	25	7.38	2.21
SW-9	19-Jan-93	8.7	7.81	3693547.26	1071746.20	15-35	35	7.18	0.63
SW-10	19-Jan-93	7.9	7.18	3693497.91	1071434.39	15-35	35	6.57	0.61
DW-1	19-Jan-93	9.7	9.50	3693848.06	1071413.61	35-45	45	8.12	1.38
DW-2	19-Jan-93	10.0	9.75	3693912.54	1071481.84	35-45	45	8.41	1.34
DW-3	19-Jan-93	9.6	9.44	3693844.95	1071415.35	55-65	65	8.23	1.21
DW-4	19-Jan-93	9.8	9.47	3693906.79	1071483.33	55-65	65	8.12	1.35
DW-5	19-Jan-93	8.7	7.44	3693544.86	1071746.48	35-45	45	6.98	0.46
DW-6	19-Jan-93	7.8	7.69	3693498.18	1071439.00	35-45	45	7.18	0.51
DW-7	19-Jan-93	10.2	10.10	3693572.21	1071353.11	40-50	50	9.02	1.08
DW-8	19-Jan-93	9.3	8.26	3693685.11	1071714.60	15-40	40	7.02	1.24
GW-1	19-Jan-93	9.0	10.42	3693796.73	1071442.05			8.89	1.53
GW-2	19-Jan-93	9.9	10.93	3693782.93	1071518.19			9.31	1.62
GW-3	19-Jan-93	10.0	10.04	3693880.03	1071460.64			7.83	2.21
GW-4	19-Jan-93	9.8	11.00	3693947.64	1071406.91			8.79	2.21

**Appendix F**  
**Well Construction Diagrams**

MW NO. DW-1 DATE 10/4/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-D1



INSPECTED BY M. Skrobacz

**Environmental  
Science &  
Engineering**

Date

Scale  
NTS

Title

**MONITOR WELL  
INSTALLATION DIAGRAM**

Drawn By

Approved By

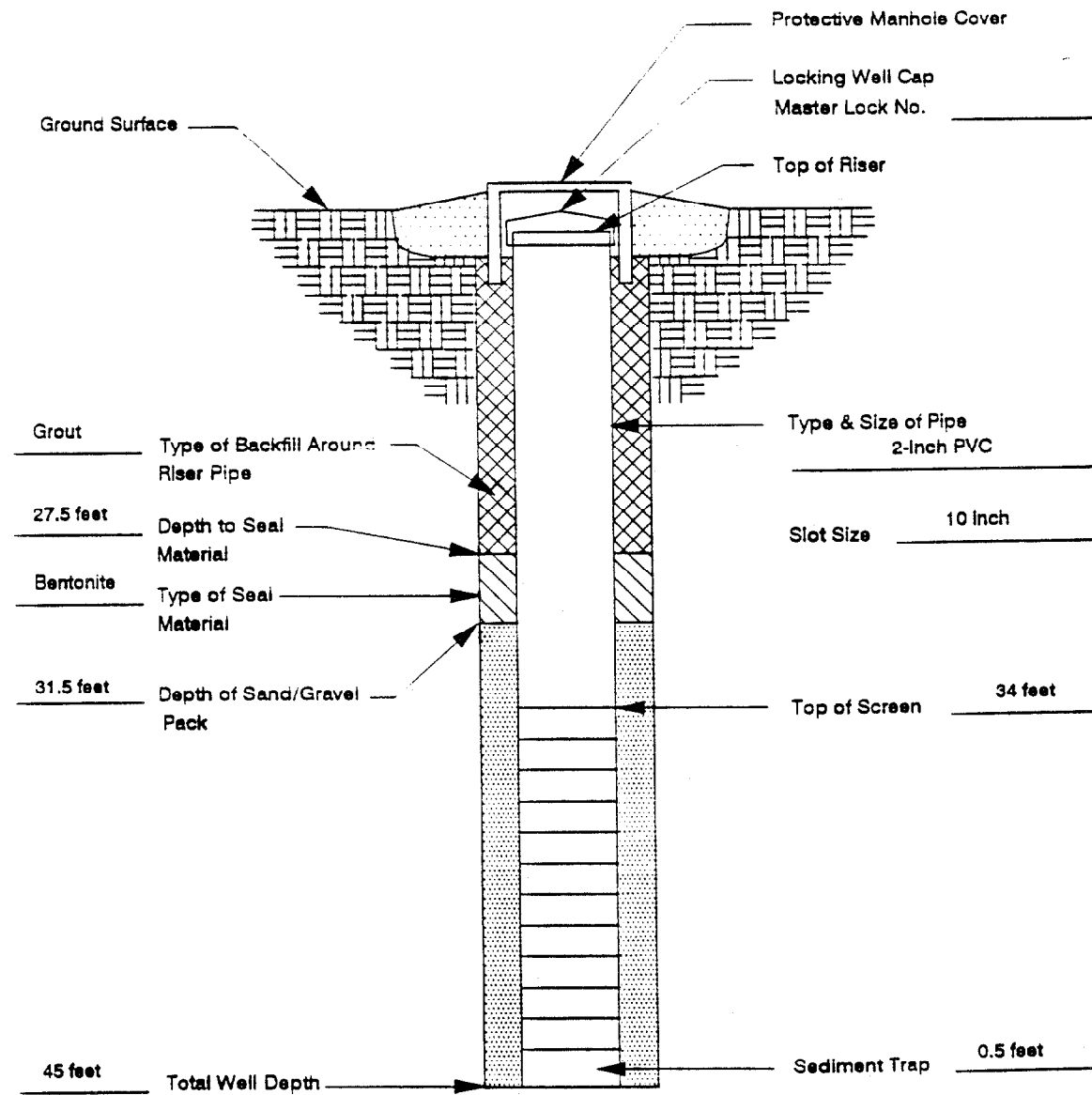
Job No.  
4921150

Dwg/Rev No  
D-1.DRW

Client  
NAVFAC

Figure

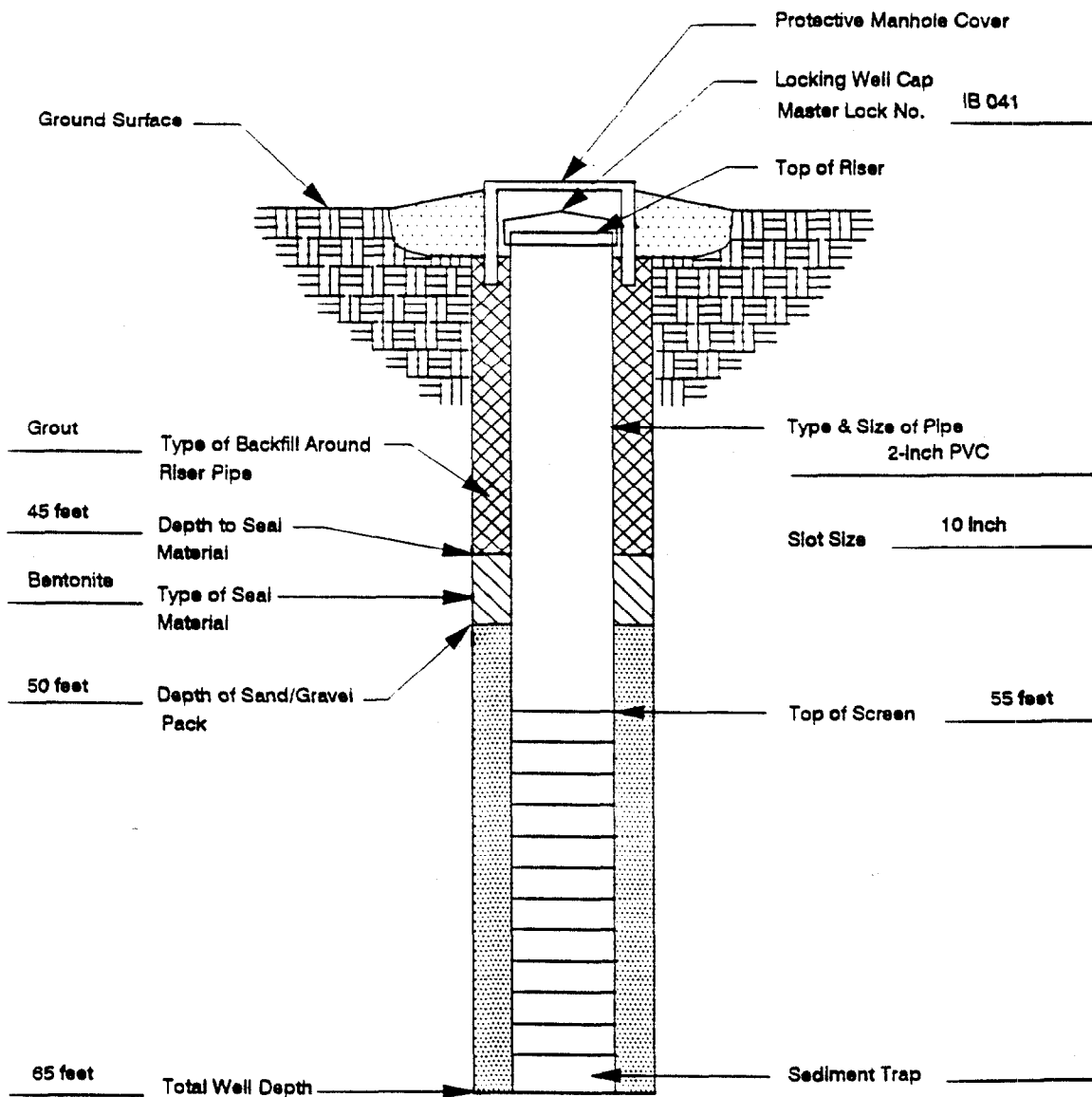
MW NO. DW-2 DATE 9/27/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-D2



INSPECTED BY M. Skrobacz

<b>Environmental Science &amp; Engineering</b>	Date	Scale NTS	<b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

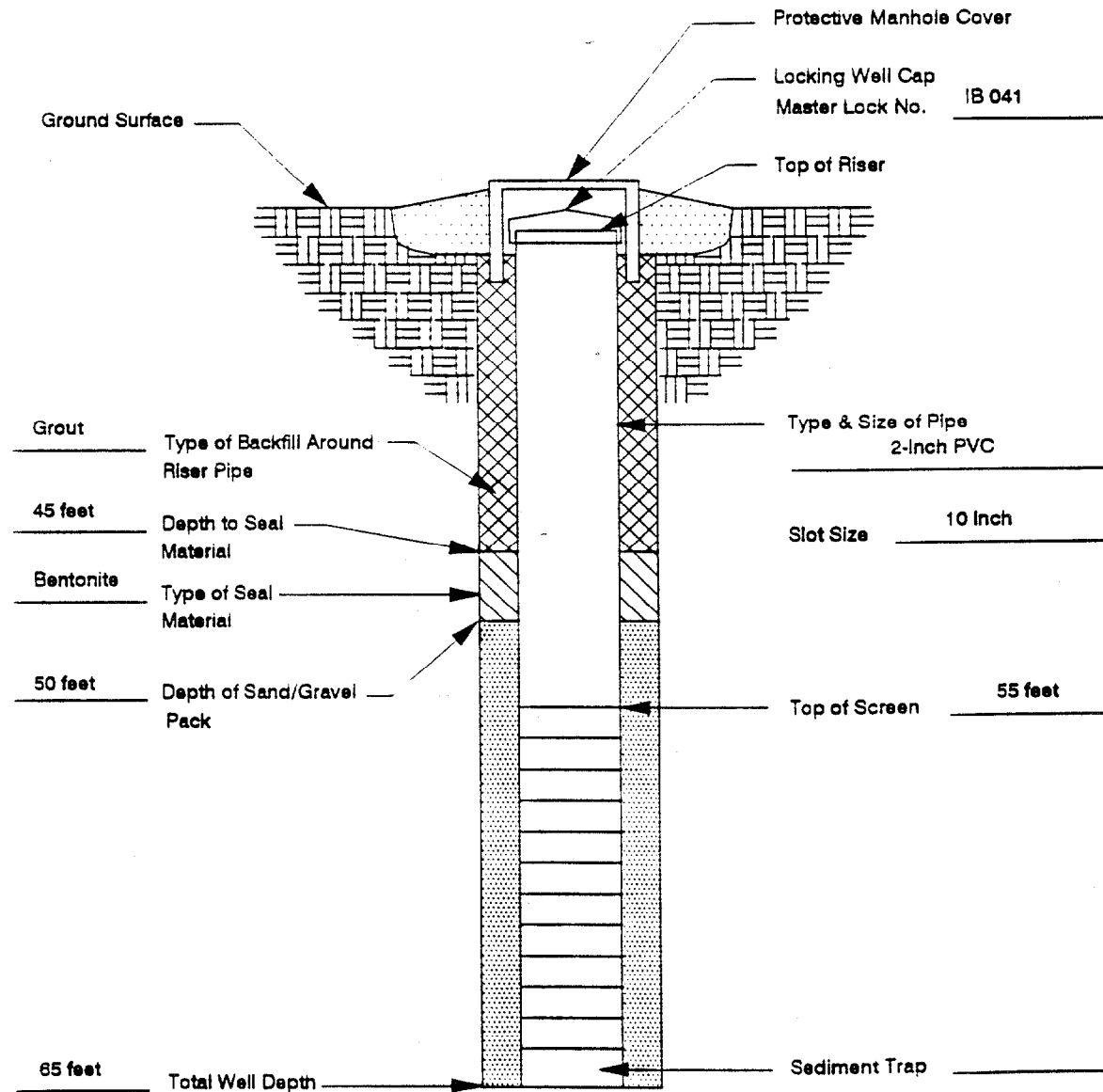
MW NO. DW-3 DATE 12/14/92  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Groundwater Systems, Inc.  
 TYPE OF RIG Acker FILE NAME 2838-D3



INSPECTED BY A. Forrest

Environmental Science & Engineering	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

MW NO. DW-4 DATE 12/14/92  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Groundwater Systems, Inc.  
 TYPE OF RIG Acker FILE NAME 2638-D4



INSPECTED BY A. Forrest

**Environmental  
Science &  
Engineering**

Date

Drawn By

Job No.  
4921150

Scale  
NTS

Approved By

Dwg/Rev No  
D-1.DRW

Title

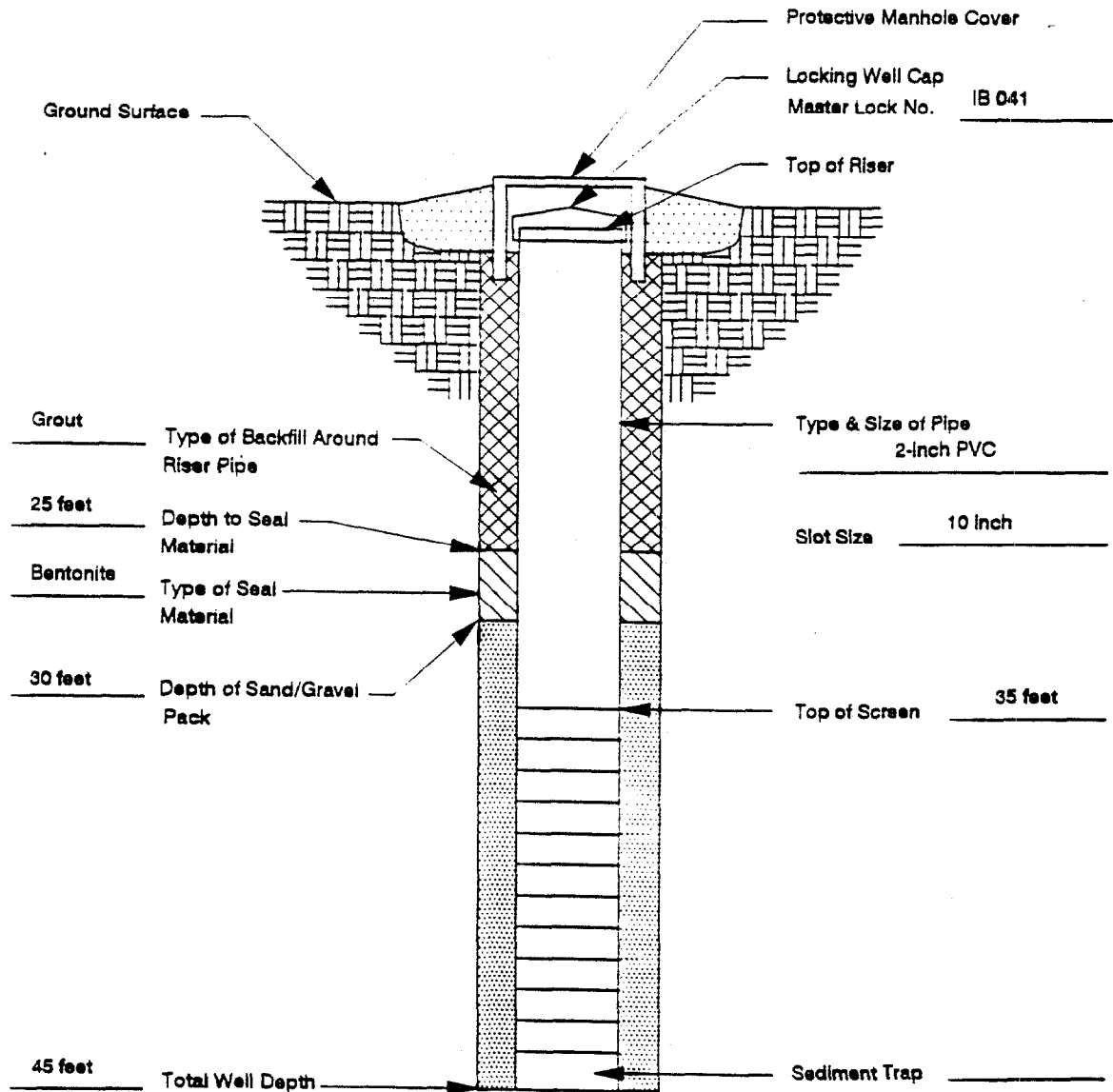
**MONITOR WELL  
INSTALLATION DIAGRAM**

Client  
NAVFAC

Figure



MW NO. DW-5 DATE 1/5/93  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Groundwater Systems, Inc.  
 TYPE OF RIG Acker FILE NAME 2638-D5



INSPECTED BY A. Forrest

**Environmental  
Science &  
Engineering**

Date

Scale  
NTS

Title

**MONITOR WELL  
INSTALLATION DIAGRAM**

Drawn By

Approved By

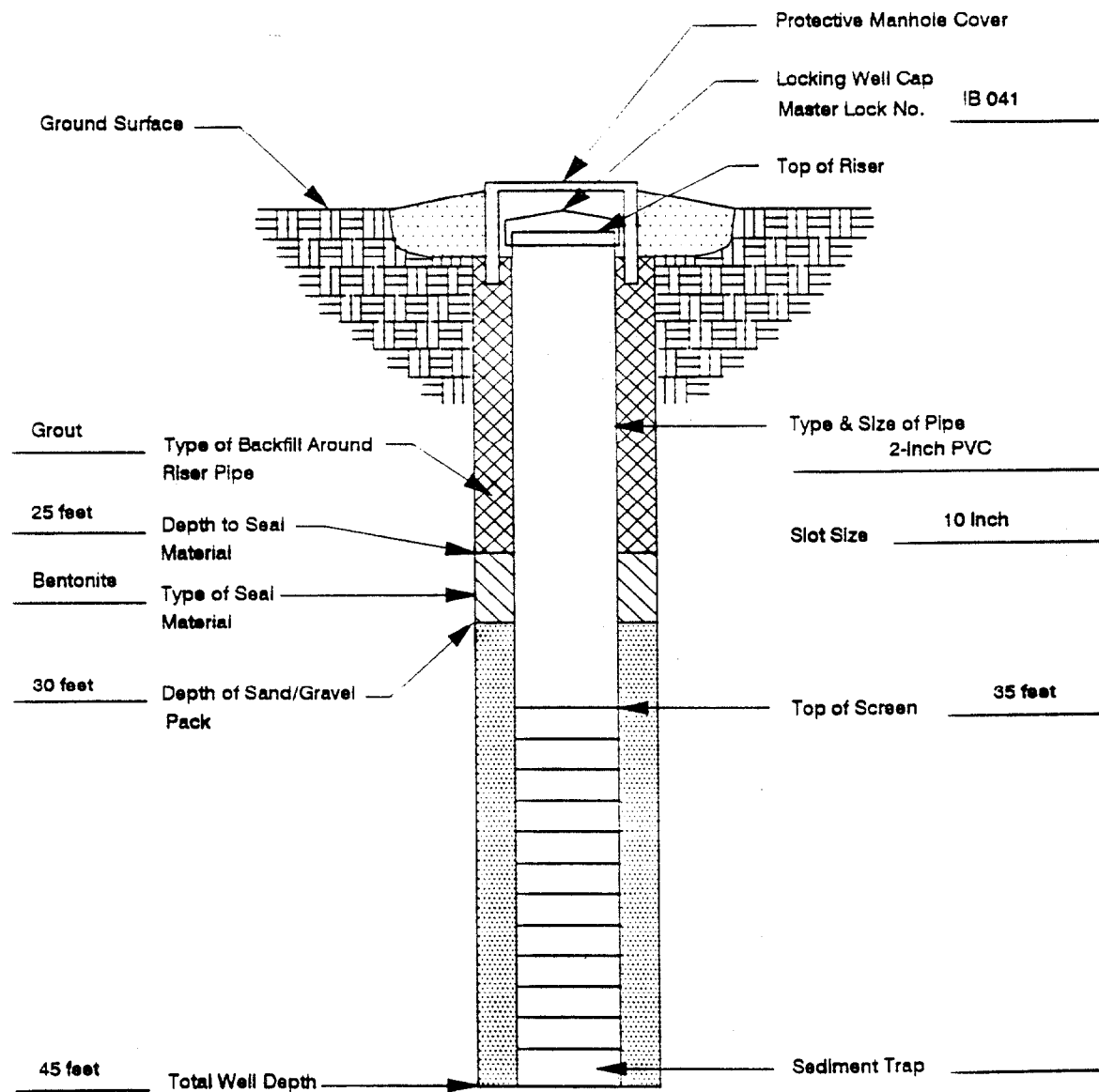
Job No. 4921150

Dwg/Rev No  
D-1.DRW

Client NAVFAC

Figure

MW NO. DW-6 DATE 1/6/93  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Groundwater Systems, Inc.  
 TYPE OF RIG Acker FILE NAME 2638-D6



INSPECTED BY A. Forrest

**Environmental  
Science &  
Engineering**

Date

Scale

NTS

Drawn By

Approved By

Job No. 4921150

Dwg/Rev No  
D-1.DRW

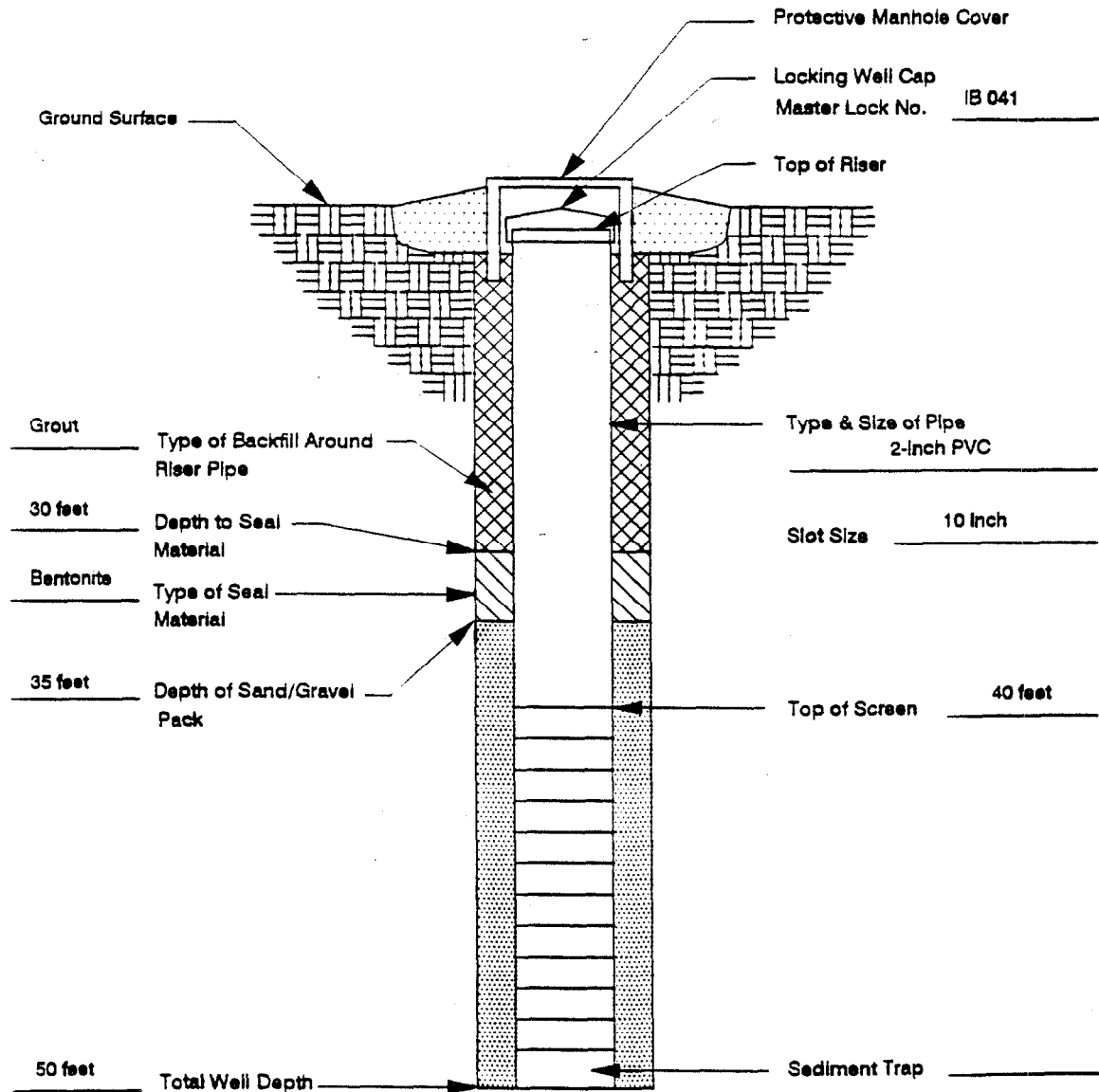
Title

**MONITOR WELL  
INSTALLATION DIAGRAM**

Client NAVFAC

Figure

MW NO. DW-7 DATE 1/7/93  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Groundwater Systems, Inc.  
 TYPE OF RIG Acker FILE NAME 2636-D7



INSPECTED BY A. Forrest

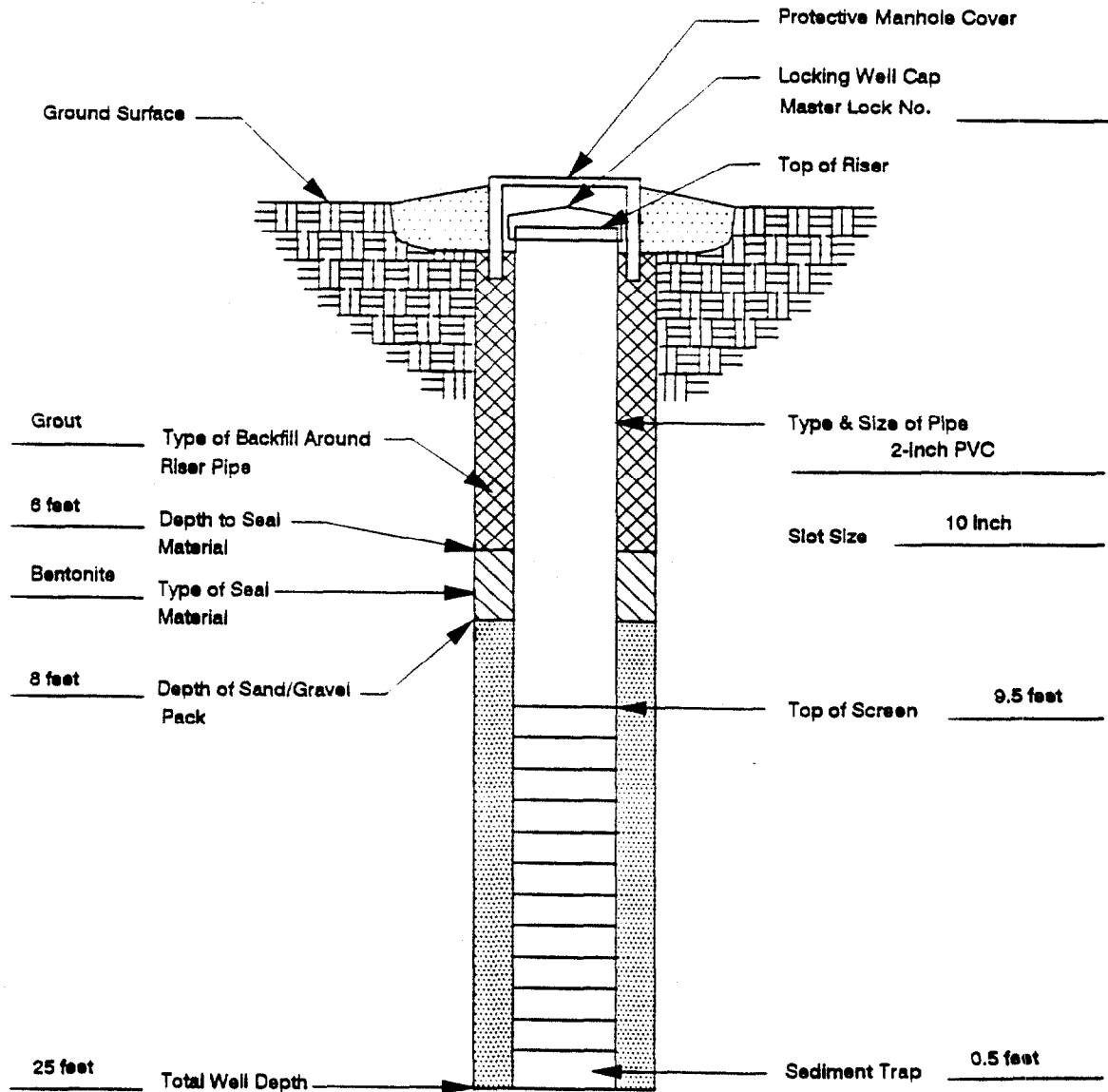
Environmental Science & Engineering	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

DATE	1/8/93
INSTALLED BY	Groundwater Systems, Inc.
FILE NAME	2635-D8



<b>Environmental Science &amp; Engineering</b>	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

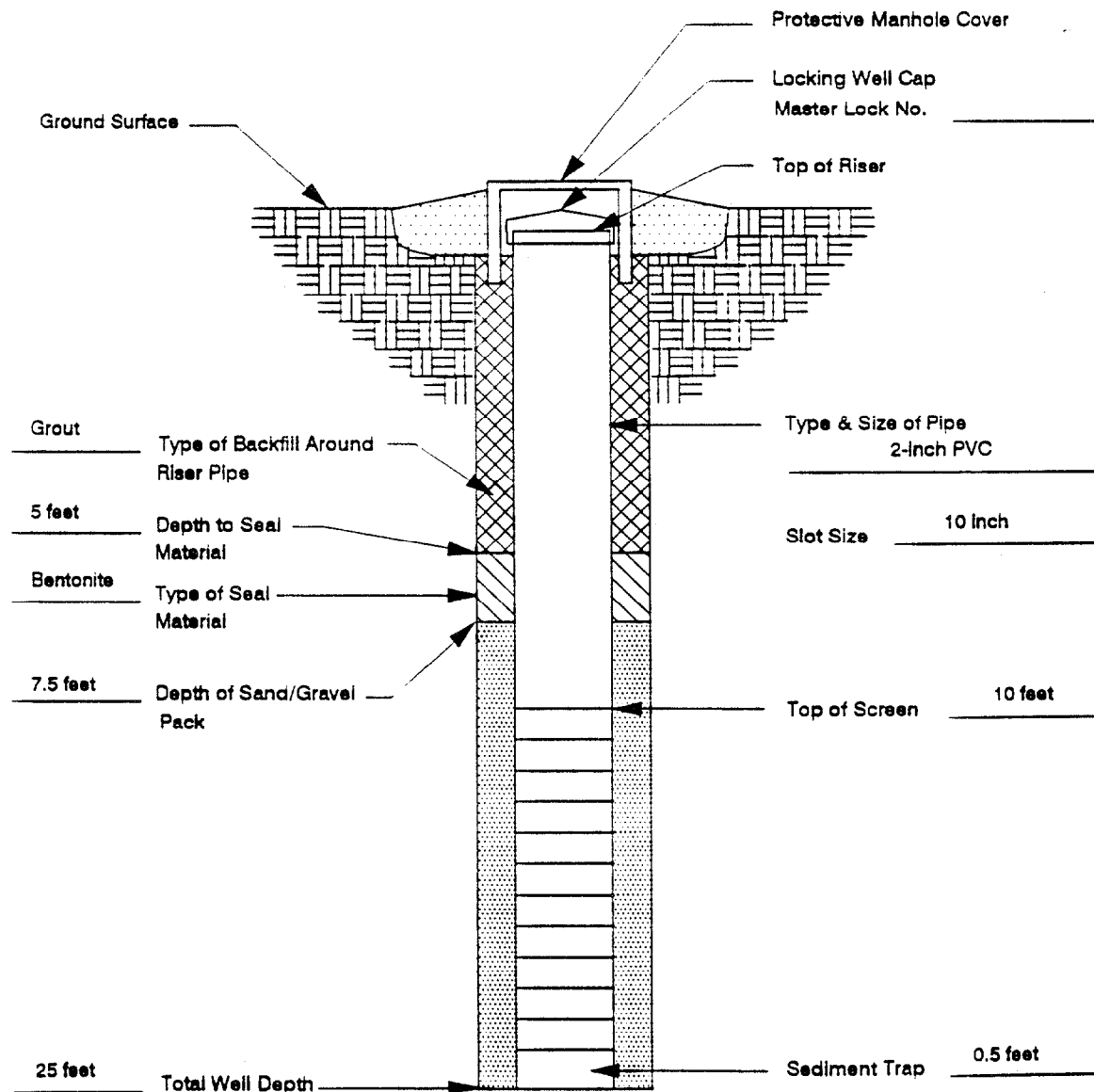
MW NO. SW-1 DATE 10/2/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-S1



INSPECTED BY M. Skrobacz

<b>Environmental Science &amp; Engineering</b>	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

MW NO. SW-2 DATE 10/1/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-S2



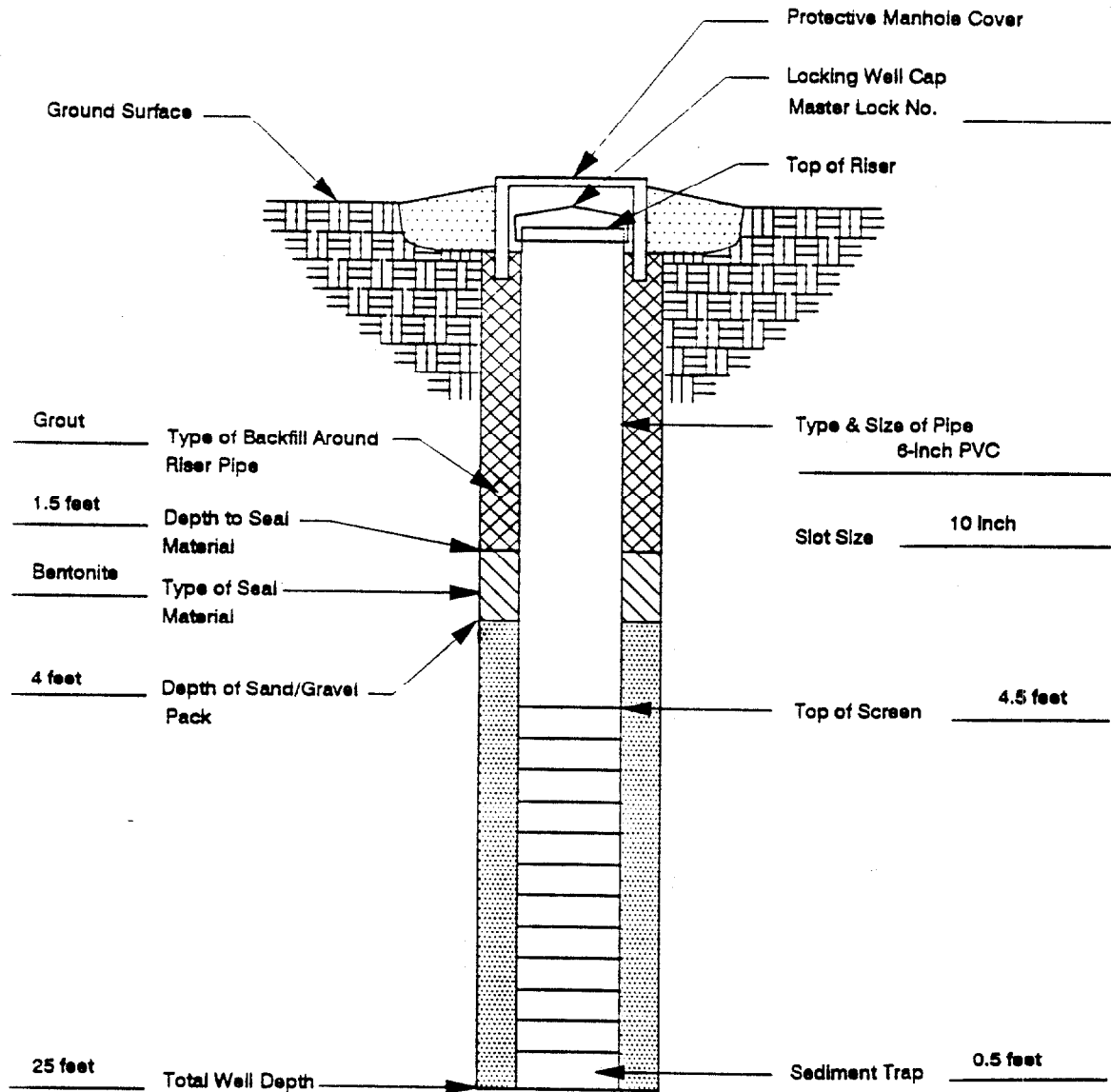
INSPECTED BY M. Skrobacz

**Environmental  
Science &  
Engineering**

Date	Scale NTS
Drawn By	Approved By
Job No. 4921150	Dwg/Rev No D-1.DRW

Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
Client NAVFAC	Figure

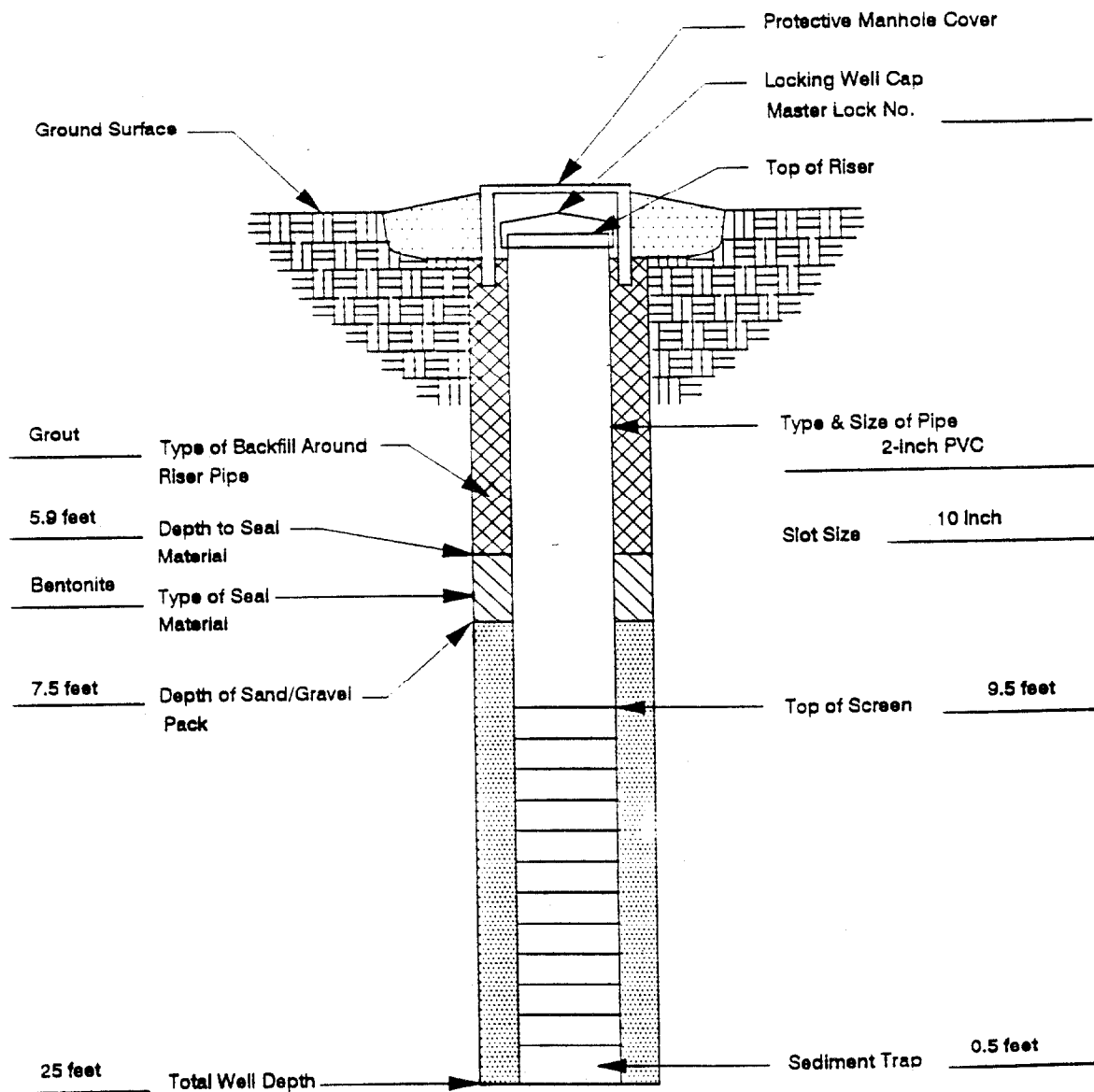
MW NO. SW-3 DATE 9/28/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-S3



INSPECTED BY M. Skrobacz

<b>Environmental Science &amp; Engineering</b>	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. <u>4921150</u>	Dwg/Rev No <u>D-1.DRW</u>	Client <u>NAVFAC</u>	Figure

MW NO. SW-4 DATE 9/26/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-S4



INSPECTED BY M. Skrobacz

**Environmental  
Science &  
Engineering**

Date

Scale

NTS

Title

**MONITOR WELL  
INSTALLATION DIAGRAM**

Drawn By

Approved By

Job No. 4921150

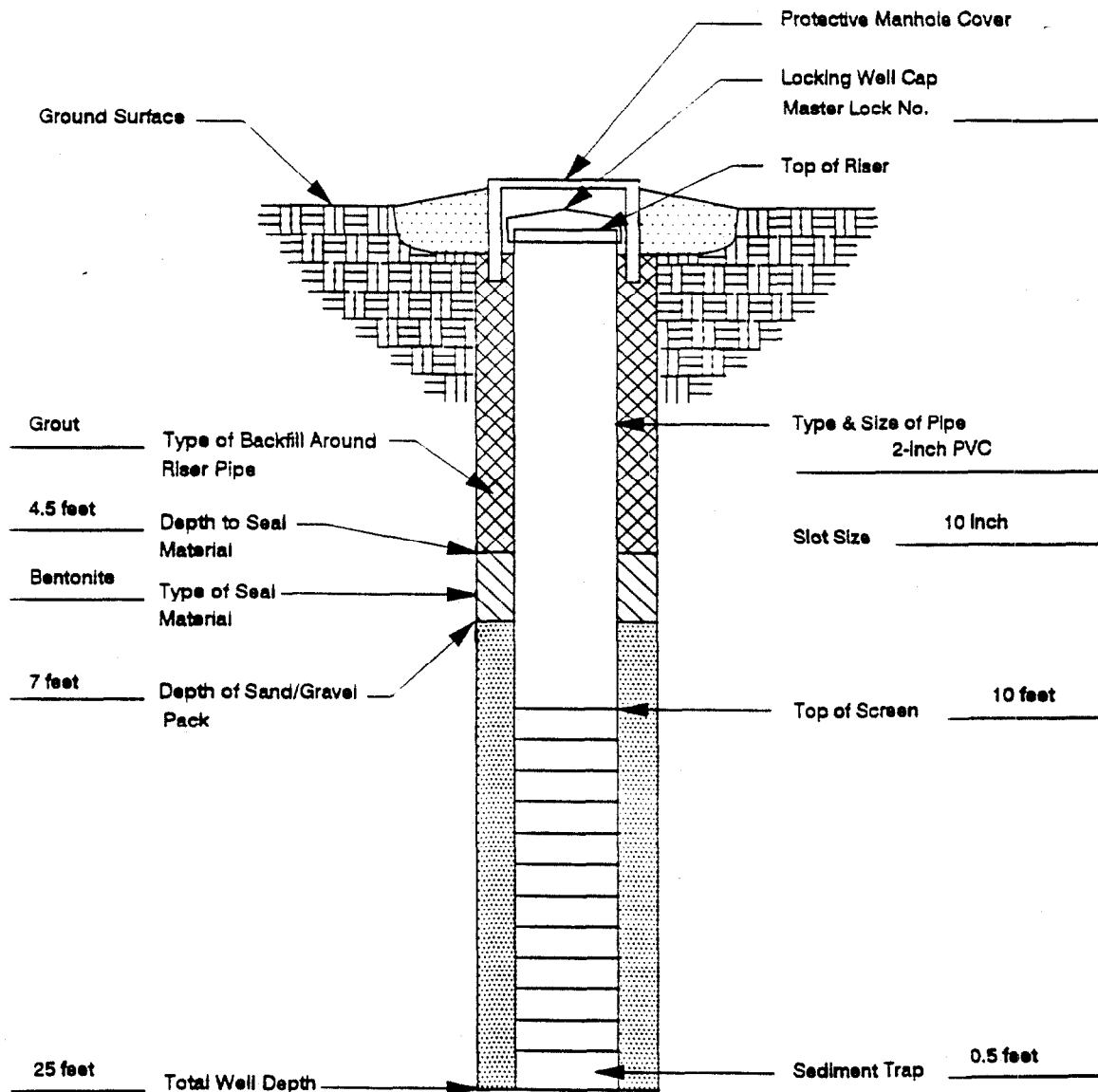
Dwg/Rev No  
D-1.DRW

Client NAVFAC

Figure



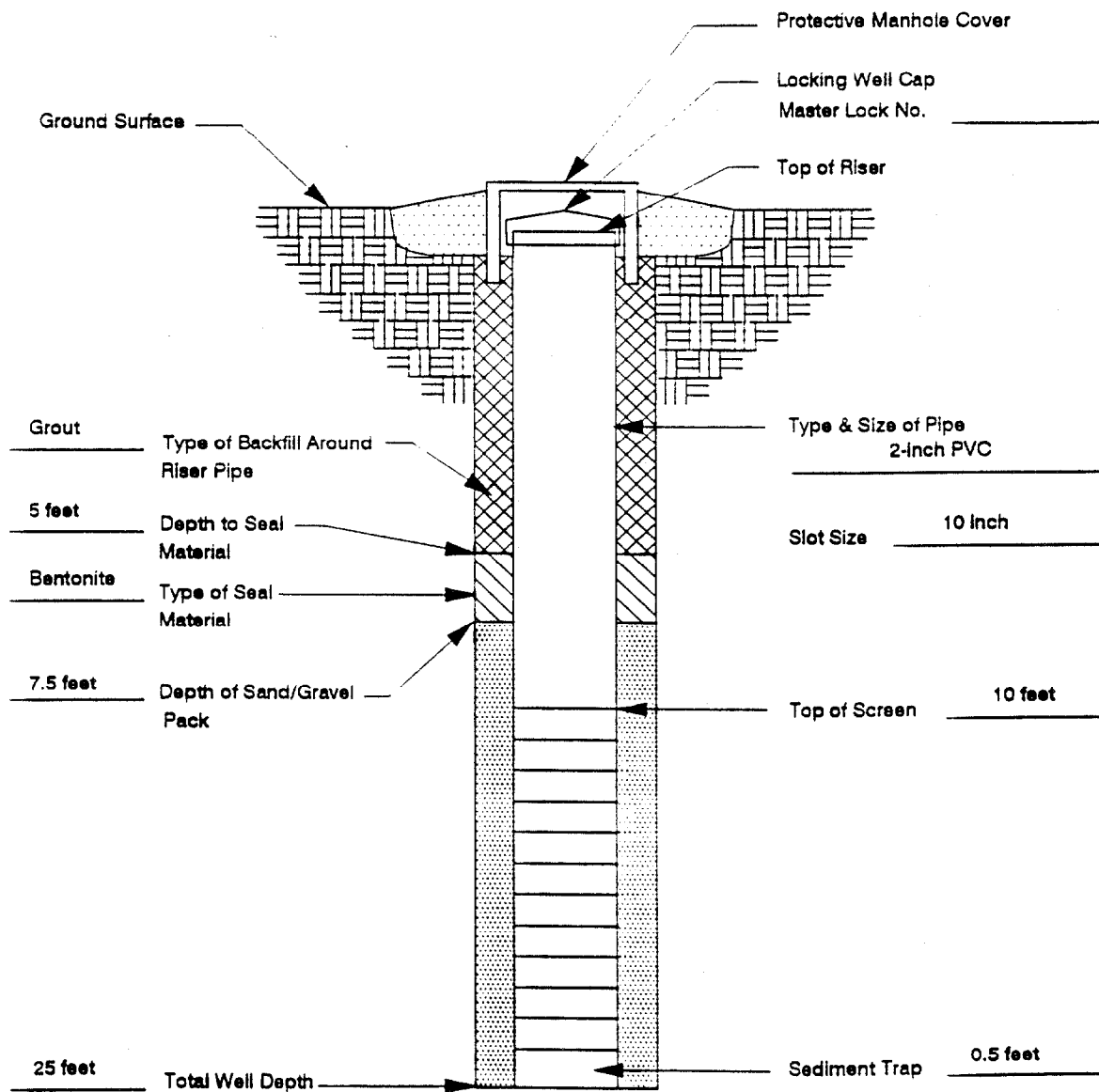
MW NO. SW-5 DATE 9/25/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-S5



INSPECTED BY M. Skrobacz

Environmental Science & Engineering	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

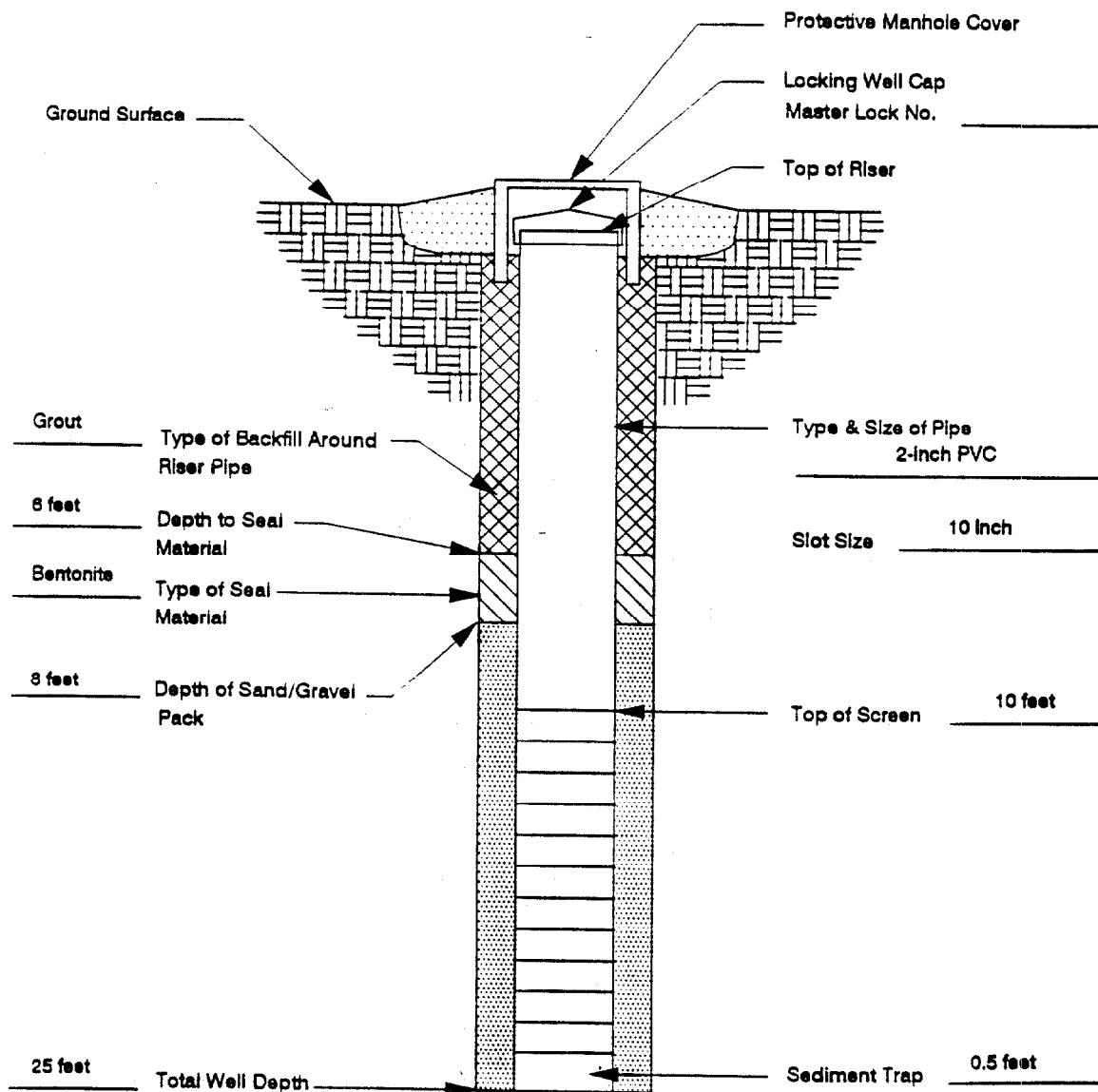
MW NO. SW-6 DATE 9/28/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2838-S6



INSPECTED BY M. Skrobacz

Environmental Science & Engineering	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

MW NO. SW-7 DATE 10/1/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 263B-S7



INSPECTED BY M. Skrobacz

**Environmental  
Science &  
Engineering**

Date

Scale  
NTS

Title

**MONITOR WELL  
INSTALLATION DIAGRAM**

Drawn By

Approved By

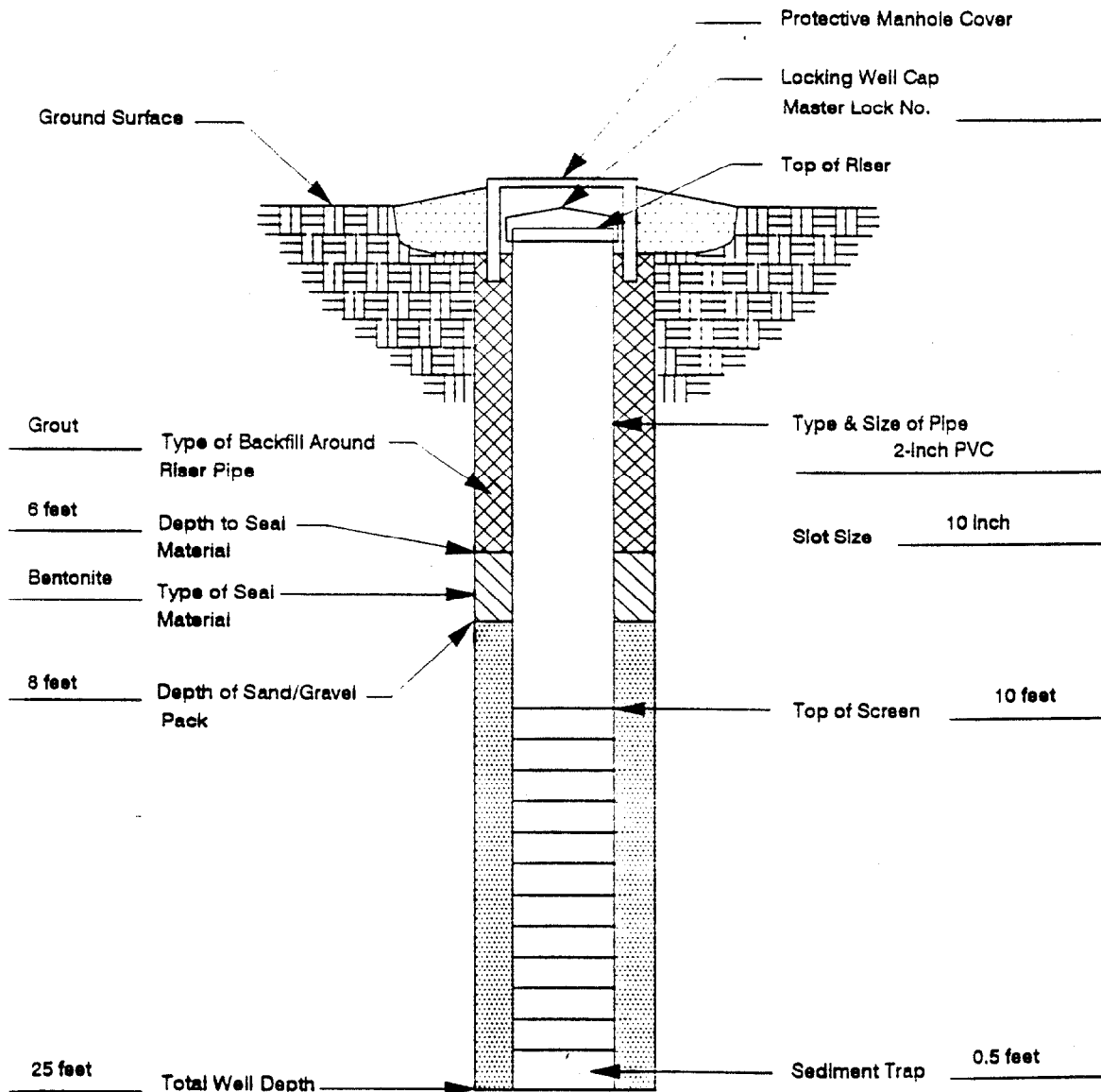
Job No. 4921150

Dwg/Rev No  
D-1.DRW

Client NAVFAC

Figure

MW NO. SW-8 DATE 9/27/90  
 PROJECT Q Area, Norfolk Naval Base INSTALLED BY Hardin-Huber  
 TYPE OF RIG Mobile FILE NAME 2638-S8

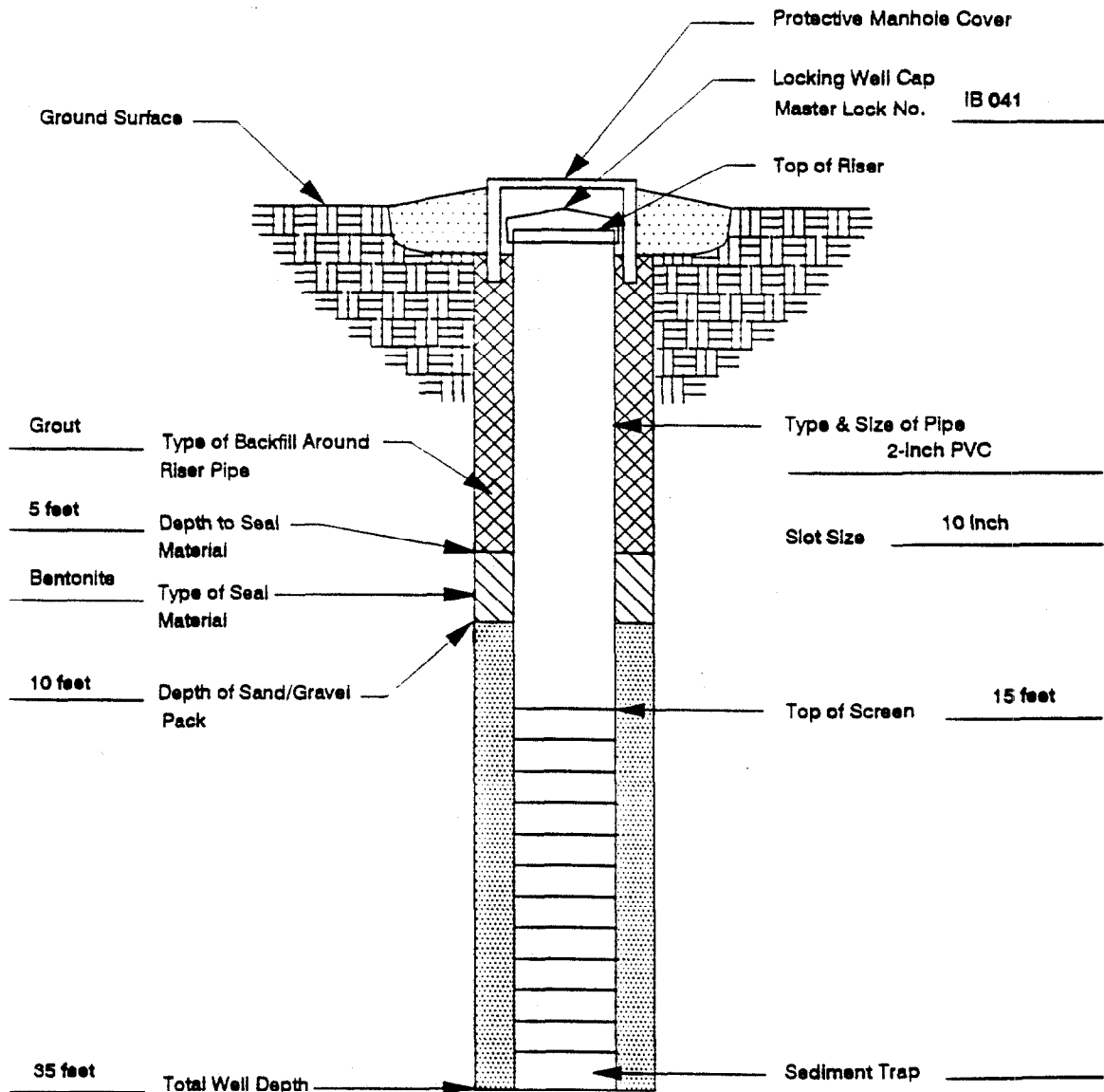


INSPECTED BY M. Skrobacz

Environmental Science & Engineering	Date	Scale NTS	Title <b>MONITOR WELL INSTALLATION DIAGRAM</b>	
	Drawn By	Approved By		
	Job No. 4921150	Dwg/Rev No D-1.DRW	Client NAVFAC	Figure

MW NO. SW-9  
 PROJECT Q Area, Norfolk Naval Base  
 TYPE OF RIG Acker

DATE 1/6/93  
 INSTALLED BY Groundwater Systems, Inc.  
 FILE NAME 2638-S9



INSPECTED BY A. Forrest

**Environmental  
Science &  
Engineering**

Date

Scale

Title

Drawn By

Approved By

**MONITOR WELL  
INSTALLATION DIAGRAM**

Job No. 4921150

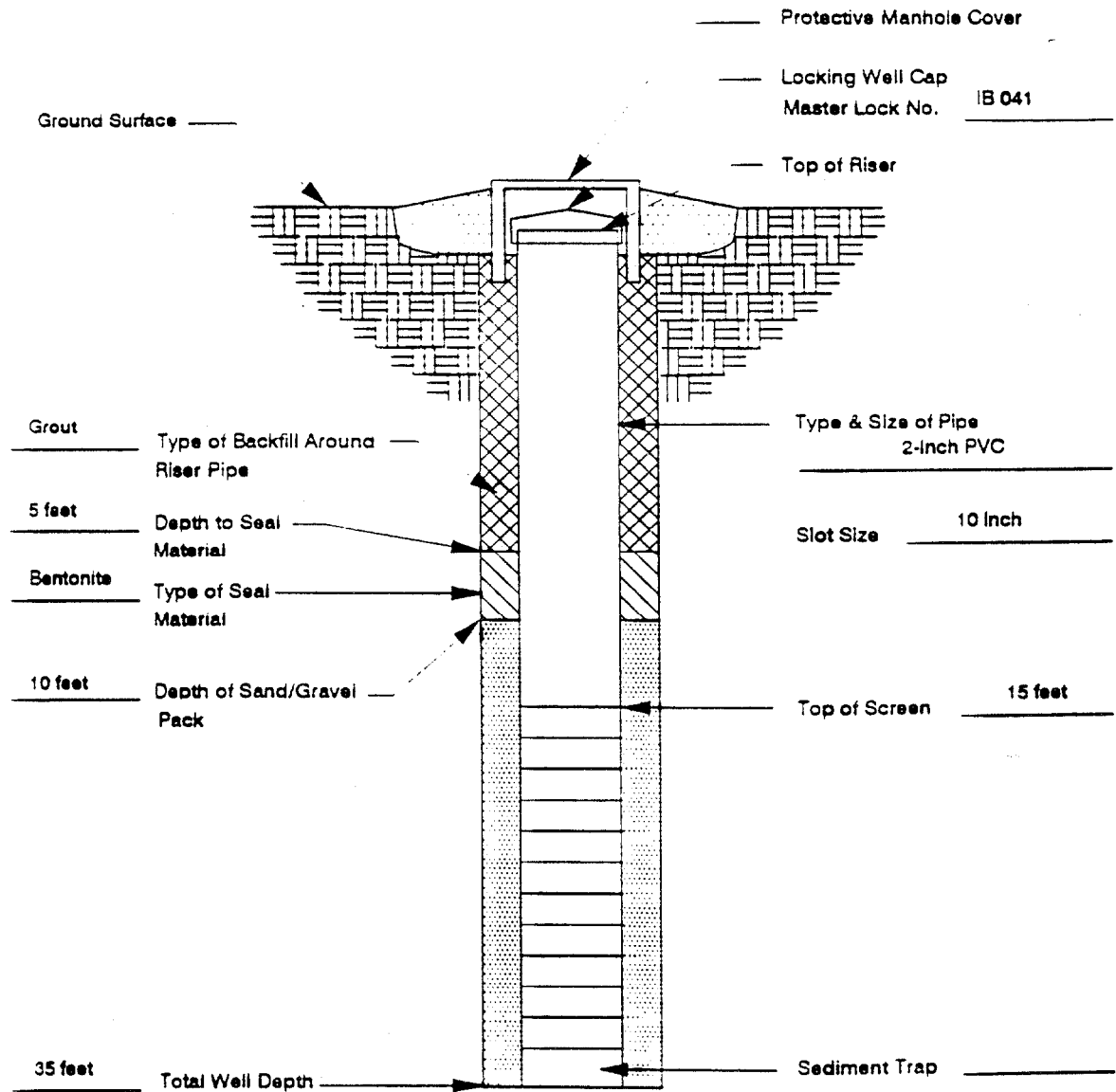
Dwg/Rev No  
D-1.DRW

Client  
NAVFAC

Figure

MW NO. SW-10  
 PROJECT Q Area, Norfolk Naval Base  
 TYPE OF RIG Acker

DATE 1/7/93  
 INSTALLED BY Groundwater Systems, Inc.  
 FILE NAME 2838-S10



INSPECTED BY A. Forrest

**Environmental  
Science &  
Engineering**

Date

Scale

Title

Drawn By

Approved By

**MONITOR WELL  
INSTALLATION DIAGRAM**

Job No. 4921150

Dwg/Rev No  
D-1.DRW

Client NAVFAC

Figure

**Appendix G**  
**RI/FS Analytical Summaries**

Table G-1. Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	TA-1-1		TA-1-2		TA-1-2-FD		TA-3-1		TA-3-2		TA-3-2RE		TA-5-1		TA-5-2		RBC			
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.				
COMPOUND																	CONC.			
CHLOROMETHANE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	220			
BROMOMETHANE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	1400			
VINYL CHLORIDE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	1.5			
CHLOROETHANE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	20000			
METHYLENE CHLORIDE	5	15	B	5	1	BJ	5	7	B	5	8	B	5	10	B	5	14	B	380	
ACETONE	10	850	E	11	23		11	U	10	59	11	370	E	11	340	E	11	540	E	100000
CARBON DISULFIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	100000	
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	4.8	
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	100000	
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	9200	
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	470	
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	31	
2-BUTANONE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	11	U	610000	
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	92000	
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	22	
VINYL ACETATE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	11	U	1000000	
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	46	
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	42	
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	18	
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	280	
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	-	
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	50	
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	99	
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	18	
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	380	
4-METHYL-2-PENTANONE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	11	U	-	
2-HEXANONE	10	U	11	U	11	U	10	U	11	U	11	U	11	U	11	U	11	U	-	
TETRACHLOROETHENE	5	2	J	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	55	
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	14	
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	200000	
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	20000	
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	100000	
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	200000	
TOTAL XYLENES	5	21	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	1000000	

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit



Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	EY-2-1		EY-2-2		EY-3-1		EY-3-2		EY-4-1		EY-4-2		RBC
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
COMPOUND													
CHLOROMETHANE	11	U	11	U	11	U	11	U	11	U	11	U	220
BROMOMETHANE	11	U	11	U	11	U	11	U	11	U	11	U	1400
VINYL CHLORIDE	11	U	11	U	11	U	11	U	11	U	11	U	1.5
CHLOROETHANE	11	U	11	U	11	U	11	U	11	U	11	U	20000
METHYLENE CHLORIDE	5	18 B	5	5 B J	5	3 B J	5	12 B	5	13 B	5	21 B	380
ACETONE	11	U	11	U	11	U	11	U	11	U	11	11	100000
CARBON DISULFIDE	5	U	5	U	5	U	5	U	5	U	5	U	100000
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	4.8
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	100000
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	9200
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	470
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	31
2-BUTANONE	11	U	11	U	11	U	11	U	11	U	11	U	610000
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	92000
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	22
VINYL ACETATE	11	U	11	U	11	U	11	U	11	U	11	U	1000000
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	48
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	42
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	18
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	280
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	-
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	50
BENZENE	5	U	5	U	5	U	5	2 J	5	U	5	U	99
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	18
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	360
4-METHYL-2-PENTANONE	11	U	11	U	11	U	11	U	11	U	11	U	-
2-HEXANONE	11	U	11	U	11	U	11	U	11	U	11	U	-
TETRACHLOROETHENE	5	11	5	U	5	U	5	U	5	U	5	U	55
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	14
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	200000
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	20000
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	100000
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	200000
TOTAL XYLENES	5	U	5	U	5	U	5	U	5	U	5	U	1000000

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded calibration range of the GC/MS instrument.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

J - Estimated value found below detection limits.

U - Compound was analyzed for but not detected.

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	EY-5-1		EY-5-2		EY-5-2FD		EY-7-1		EY-7-2		RBC
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	11	U	11	U	11	U	11	U	11	U	220
BROMOMETHANE	11	U	11	U	11	U	11	U	11	U	1400
VINYL CHLORIDE	11	U	11	U	11	U	11	U	11	U	1.5
CHLOROETHANE	11	U	11	U	11	U	11	U	11	U	20000
METHYLENE CHLORIDE	5	19 B	5	13 B	5	13 B	5	12 B	5	12 B	380
ACETONE	11	U	11	U	11	U	11	U	11	7 J	100000
CARBON DISULFIDE	5	U	5	U	5	U	5	U	6	U	100000
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	6	U	4.8
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	6	U	100000
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	6	U	9200
CHLOROFORM	5	U	5	U	5	U	5	U	6	U	470
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	6	U	31
2-BUTANONE	11	U	11	U	11	U	11	U	11	U	610000
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	6	U	92000
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	6	U	22
VINYL ACETATE	11	U	11	U	11	U	11	U	11	U	1000000
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	6	U	46
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	6	U	42
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	6	U	16
TRICHLOROETHENE	5	U	5	U	5	U	5	U	6	U	260
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	6	U	-
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	6	U	50
BENZENE	5	U	5	U	5	U	5	U	6	U	99
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	6	U	16
BROMOFORM	5	U	5	U	5	U	5	U	6	U	360
4-METHYL-2-PENTANONE	11	U	11	U	11	U	11	U	11	U	-
2-HEXANONE	11	U	11	U	11	U	11	U	11	U	-
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	6	U	55
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	6	U	14
TOLUENE	5	U	5	U	5	U	5	U	6	U	200000
CHLOROBENZENE	5	U	5	U	5	U	5	U	6	U	20000
ETHYLBENZENE	5	U	5	U	5	U	5	U	6	U	100000
STYRENE	5	U	5	U	5	U	5	U	6	U	200000
TOTAL XYLENES	5	U	5	U	5	U	5	U	6	U	1000000

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

J - Estimated value found below detection limits.

U - Compound was analyzed for but not detected.

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	HM-2-1		HM-2-2		HM-3-1		HM-3-2		HM-4-1		HM-4-1FD		HM-4-2		HM-5-1		RBC		
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	CONC.		
CHLOROMETHANE	11	U	11	U	11	U	11	U	11	U	11	U	11	U	11	U	220		
BROMOMETHANE	11	U	11	U	11	U	11	U	11	U	11	U	11	U	11	U	1400		
VINYL CHLORIDE	11	U	11	U	11	U	11	U	11	U	11	U	11	U	11	U	1.5		
CHLOROETHANE	11	U	11	U	11	U	11	U	11	U	11	U	11	U	11	U	20000		
METHYLENE CHLORIDE	5	2	BJ	5	U	5	3	J	5	U	5	12	B	8	U	5	31	B	380
ACETONE	11	U	11	U	11	U	11	57	11	27	11	28	11	8	J	11	U	100000	
CARBON DISULFIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	100000		
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	4.8		
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	100000		
1,2-DICHLOROETHENE	5	U	5	U	5	20	5	U	5	U	5	5	J	5	U	5	U	9200	
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	470		
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	31		
2-BUTANONE	11	U	11	U	11	U	11	U	11	U	11	U	11	U	11	U	610000		
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	92000		
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	22		
VINYL ACETATE	11	U	11	U	11	U	11	U	11	U	11	U	11	U	11	U	1000000		
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	46		
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	42		
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	18		
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	280		
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	-		
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	50		
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	99		
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	18		
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	360		
4-METHYL-2-PENTANONE	11	U	11	U	11	U	11	U	11	U	11	3	J	11	U	11	U	-	
2-HEXANONE	11	U	11	U	11	U	11	U	11	U	11	U	11	U	11	U	-		
TETRACHLOROETHENE	5	U	5	U	5	4	J	5	U	5	10	5	17	5	4	J	5	U	55
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	14		
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	200000		
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	20000		
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	100000		
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	200000		
TOTAL XYLENES	5	U	5	U	5	U	5	U	5	U	5	U	5	U	5	U	1000000		

B - Analyte was found in the associated blank.

U - Compound was analyzed for but not detected.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	SW-1		SW-2		SW-3		RBC
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	14	U	14	U	12	U	220
BROMOMETHANE	14	U	14	U	12	U	1400
VINYL CHLORIDE	14	U	14	U	12	U	1.5
CHLOROETHANE	14	U	14	U	12	U	20000
METHYLENE CHLORIDE	7	8	7	U	6	9	380
ACETONE	14	450	14	450	12	150	100000
CARBON DISULFIDE	7	U	7	U	6	U	100000
1,1-DICHLOROETHENE	7	U	7	5	6	U	4.8
1,1-DICHLOROETHANE	7	U	7	U	6	U	100000
1,2-DICHLOROETHENE	7	U	7	U	6	U	9200
CHLOROFORM	7	U	7	U	6	U	470
1,2-DICHLOROETHANE	7	U	7	U	6	U	31
2-BUTANONE	14	U	14	U	12	U	610000
1,1,1-TRICHLOROETHANE	7	U	7	U	6	U	92000
CARBON TETRACHLORIDE	7	U	7	U	6	U	22
VINYL ACETATE	14	U	14	U	12	U	1000000
BROMODICHLOROMETHANE	7	U	7	U	6	U	48
1,2-DICHLOROPROPANE	7	U	7	U	6	U	42
CIS-1,3-DICHLOROPROPENE	7	U	7	U	6	U	16
TRICHLOROETHENE	7	U	7	U	6	U	280
DIBROMOCHLOROMETHANE	7	U	7	U	6	U	-
1,1,2-TRICHLOROETHANE	7	U	7	U	6	U	50
BENZENE	7	U	7	U	6	U	99
TRANS-1,3-DICHLOROPROPENE	7	U	7	U	6	U	16
BROMOFORM	7	U	7	U	6	U	380
4-METHYL-2-PENTANONE	14	U	14	U	12	U	-
2-HEXANONE	14	U	14	U	12	U	-
TETRACHLOROETHENE	7	7	7	7	6	U	55
1,1,2,2-TETRACHLOROETHANE	7	U	7	U	6	U	14
TOLUENE	7	U	7	U	6	U	200000
CHLOROBENZENE	7	U	7	U	6	U	20000
ETHYLBENZENE	7	U	7	U	6	U	100000
STYRENE	7	U	7	U	6	U	200000
TOTAL XYLENES	7	U	7	U	6	U	1000000

B - Analyte was found in the associated blank.

J - Estimated value that was found below detection limits

U - Compound was analyzed for but not detected.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	HM-5-2		HM-7-1		HM-7-2		HM-8-1		HM-8-2		HM-10-1		HM-10-2		RBC
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	220
BROMOMETHANE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	1400
VINYL CHLORIDE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	1.5
CHLOROETHANE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	20000
METHYLENE CHLORIDE	8	24	B	5	12	B	5	8	B	54	110	B	5	3	380
ACETONE	12	U	11	U	11	U	10	U	110	9	J	10	U	11	100000
CARBON DISULFIDE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	100000
1,1-DICHLOROETHENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	4.8
1,1-DICHLOROETHANE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	100000
1,2-DICHLOROETHENE	8	18	5	15	5	U	5	U	54	U	5	U	5	U	9200
CHLOROFORM	8	U	5	U	5	U	5	U	54	U	5	U	5	U	470
1,2-DICHLOROETHANE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	31
2-BUTANONE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	810000
1,1,1-TRICHLOROETHANE	8	U	5	U	5	U	5	U	54	U	5	1	J	5	92000
CARBON TETRACHLORIDE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	22
VINYL ACETATE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	1000000
BROMODICHLOROMETHANE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	48
1,2-DICHLOROPROPANE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	42
CIS-1,3-DICHLOROPROPENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	18
TRICHLOROETHENE	8	U	5	29	B	5	U	5	U	54	U	5	U	5	280
DIBROMOCHLOROMETHANE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	
1,1,2-TRICHLOROETHANE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	50
BENZENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	89
TRANS-1,3-DICHLOROPROPENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	18
BROMOFORM	8	U	5	U	5	U	5	U	54	U	5	U	5	U	380
4-METHYL-2-PENTANONE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	
2-HEXANONE	12	U	11	U	11	U	10	U	110	U	10	U	11	U	
TETRACHLOROETHENE	8	U	5	U	5	U	5	98	54	3200	E	5	150	5	55
1,1,2,2-TETRACHLOROETHANE	8	U	5	U	5	U	5	U	54	30	J	5	U	5	14
TOLUENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	200000
CHLOROBENZENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	20000
ETHYLBENZENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	100000
STYRENE	8	U	5	U	5	U	5	U	54	U	5	U	5	U	200000
TOTAL XYLENES	8	U	5	U	5	U	5	U	54	U	5	U	5	U	1000000

B - Analyte was found in the associated blank.

U - Compound was analyzed for but not detected.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

J - Estimated value that was found below detection limits.

E - Analyte was found above upper detection limits.

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	PP-2-1		PP-2-2		PP-3-1		PP-3-1RE		PP-3-1FD		PP-3-2		RBC	
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.		
COMPOUND														
CHLOROMETHANE	54	U	11	U	11	U	11	U	10	U	11	U	220	
BROMOMETHANE	54	U	11	U	11	U	11	U	10	U	11	U	1400	
VINYL CHLORIDE	54	U	11	U	11	U	11	U	10	U	11	U	1.5	
CHLOROETHANE	54	U	11	U	11	U	11	U	10	U	11	U	20000	
METHYLENE CHLORIDE	27	39	5	U	5	28	5	18	5	U	5	U	380	
ACETONE	54	U	11	U	11	U	11	U	10	U	11	U	100000	
CARBON DISULFIDE	27	U	5	U	5	U	5	U	5	U	5	U	100000	
1,1-DICHLOROETHENE	27	U	5	U	5	U	5	U	5	U	5	U	4.8	
1,1-DICHLOROETHANE	27	U	5	U	5	U	5	U	5	U	5	U	100000	
1,2-DICHLOROETHENE	27	1500	E	5	U	5	U	5	U	5	U	5	U	9200
CHLOROFORM	27	U	5	U	5	U	5	U	5	U	5	U	470	
1,2-DICHLOROETHANE	27	U	5	U	5	U	5	U	5	U	5	U	31	
2-BUTANONE	54	U	11	U	11	U	11	U	10	U	11	U	810000	
1,1,1-TRICHLOROETHANE	27	U	5	U	5	U	5	U	5	U	5	U	92000	
CARBON TETRACHLORIDE	27	U	5	U	5	U	5	U	5	U	5	U	22	
VINYL ACETATE	54	U	11	U	11	U	11	U	10	U	11	U	1000000	
BROMODICHLOROMETHANE	27	U	5	U	5	U	5	U	5	U	5	U	46	
1,2-DICHLOROPROPANE	27	U	5	U	5	U	5	U	5	U	5	U	42	
CIS-1,3-DICHLOROPROPENE	27	U	5	U	5	U	5	U	5	U	5	U	18	
TRICHLOROETHENE	27	U	5	U	5	U	5	U	5	U	5	U	260	
DIBROMOCHLOROMETHANE	27	U	5	U	5	U	5	U	5	U	5	U		
1,1,2-TRICHLOROETHANE	27	U	5	U	5	U	5	U	5	U	5	U	50	
BENZENE	27	U	5	U	5	U	5	U	5	U	5	U	99	
TRANS-1,3-DICHLOROPROPENE	27	U	5	U	5	U	5	U	5	U	5	U	18	
BROMOFORM	27	U	5	U	5	U	5	U	5	U	5	U	380	
4-METHYL-2-PENTANONE	54	U	11	U	11	U	11	U	10	U	11	U		
2-HEXANONE	54	U	11	U	11	U	11	U	10	U	11	U		
TETRACHLOROETHENE	27	150	5	U	5	U	5	U	5	U	5	U	55	
1,1,2,2-TETRACHLOROETHANE	27	U	5	U	5	U	5	U	5	U	5	U	14	
TOLUENE	27	140	5	U	5	U	5	U	5	U	5	U	200000	
CHLOROBENZENE	27	U	5	U	5	U	5	U	5	U	5	U	20000	
ETHYLBENZENE	27	U	5	U	5	U	5	U	5	U	5	U	100000	
STYRENE	27	U	5	U	5	U	5	U	5	U	5	U	200000	
TOTAL XYLENES	27	U	5	U	5	U	5	U	5	U	5	U	1000000	

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

U - Compound was analyzed for but not detected

J - Estimated concentration found below detection limits

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)													
SAMPLE NO.	PP-5-1		PP-5-2		PP-8-1		PP-8-2		PP-8-1		PP-8-2		RBC
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	CONC.
CHLOROMETHANE	11	U	11	U	11	U	11	U	11	U	11	U	220
BROMOMETHANE	11	U	11	U	11	U	11	U	11	U	11	U	1400
VINYL CHLORIDE	11	U	11	U	11	U	11	U	11	U	11	U	1.5
CHLOROETHANE	11	U	11	U	11	U	11	U	11	U	11	U	20000
METHYLENE CHLORIDE	5	4	J	5	U	5	22	5	20	5	25	B	380
ACETONE	11	6	J	11	7	J	11	12	11	25	11	U	100000
CARBON DISULFIDE	5	U	5	U	5	U	5	U	5	U	5	U	100000
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	4.8
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	100000
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	9200
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	470
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	31
2-BUTANONE	11	U	11	U	11	U	11	U	11	U	11	U	610000
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	92000
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	22
VINYL ACETATE	11	U	11	U	11	U	11	U	11	U	11	U	1000000
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	48
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	42
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	16
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	260
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	-
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	50
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U	99
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	16
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	360
4-METHYL-2-PENTANONE	11	U	11	U	11	U	11	U	11	U	11	U	-
2-HEXANONE	11	U	11	U	11	U	11	U	11	U	11	U	-
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	55
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	14
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	200000
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	20000
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	100000
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	200000
TOTAL XYLENES	5	U	5	U	5	U	5	U	5	U	5	U	1000000

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

SAMPLE NO.	PP-9-1		PP-9-2		PP-11-1		PP-11-2		PP-12-1		PP-12-2		RBC	
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.		
COMPOUND													CONC.	
CHLOROMETHANE	11	U	12	U	11	U	11	U	11	U	11	U	220	
BROMOMETHANE	11	U	12	U	11	U	11	U	11	U	11	U	1400	
VINYL CHLORIDE	11	U	12	U	11	U	11	U	11	U	11	U	1.5	
CHLOROETHANE	11	U	12	U	11	U	11	U	11	U	11	U	20000	
METHYLENE CHLORIDE	5	8	B	5	25	B	5	9	5	24	5	10	B	380
ACETONE	11	8	J	12	8	J	11	U	11	14	11	U	100000	
CARBON DISULFIDE	5	U	8	U	5	U	5	U	5	U	5	U	100000	
1,1-DICHLOROETHENE	5	U	8	U	5	U	5	U	5	U	5	U	4.8	
1,1-DICHLOROETHANE	5	U	8	U	5	U	5	U	5	U	5	U	100000	
1,2-DICHLOROETHENE	5	U	8	U	5	U	5	U	5	U	5	U	9200	
CHLOROFORM	5	U	8	U	5	U	5	U	5	U	5	U	470	
1,2-DICHLOROETHANE	5	U	8	U	5	U	5	U	5	U	5	U	31	
2-BUTANONE	11	U	12	U	11	U	11	U	11	U	11	U	610000	
1,1,1-TRICHLOROETHANE	5	U	8	U	5	U	5	U	5	U	5	U	92000	
CARBON TETRACHLORIDE	5	U	8	U	5	U	5	U	5	U	5	U	22	
VINYL ACETATE	11	U	12	U	11	U	11	U	11	U	11	U	1000000	
BROMODICHLOROMETHANE	5	U	8	U	5	U	5	U	5	U	5	U	46	
1,2-DICHLOROPROPANE	5	U	8	U	5	U	5	U	5	U	5	U	42	
CIS-1,3-DICHLOROPROPENE	5	U	8	U	5	U	5	U	5	U	5	U	16	
TRICHLOROETHENE	5	U	8	U	5	U	5	U	5	U	5	U	260	
DIBROMOCHLOROMETHANE	5	U	8	U	5	U	5	U	5	U	5	U	-	
1,1,2-TRICHLOROETHANE	5	U	8	U	5	U	5	U	5	U	5	U	50	
BENZENE	5	U	8	U	5	U	5	U	5	U	5	U	99	
TRANS-1,3-DICHLOROPROPENE	5	U	8	U	5	U	5	U	5	U	5	U	16	
BROMOFORM	5	U	8	U	5	U	5	U	5	U	5	U	360	
4-METHYL-2-PENTANONE	11	U	12	U	11	U	11	U	11	U	11	U	-	
2-HEXANONE	11	U	12	U	11	U	11	U	11	U	11	U	-	
TETRACHLOROETHENE	5	U	8	U	5	U	5	U	5	10	5	U	55	
1,1,2,2-TETRACHLOROETHANE	5	U	8	U	5	U	5	U	5	U	5	U	14	
TOLUENE	5	U	8	U	5	U	5	U	5	U	5	U	200000	
CHLOROBENZENE	5	U	8	U	5	U	5	U	5	U	5	U	20000	
ETHYLBENZENE	5	U	8	U	5	U	5	U	5	U	5	U	100000	
STYRENE	5	U	8	U	5	U	5	U	5	U	5	U	200000	
TOTAL XYLENES	5	U	8	U	5	U	5	U	5	U	5	U	1000000	

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected.



Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)							
SAMPLE NO.	PP-14-1		PP-14-2		PP-14-2FD		RBC
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	CONC.
CHLOROMETHANE	11	U	11	U	11	U	220
BROMOMETHANE	11	U	11	U	11	U	1400
VINYL CHLORIDE	11	U	11	U	11	U	1.5
CHLOROETHANE	11	U	11	U	11	U	20000
METHYLENE CHLORIDE	5	34	U	5	7	B	380
ACETONE	11	U	11	U	11	U	100000
CARBON DISULFIDE	5	U	5	U	5	U	100000
1,1-DICHLOROETHENE	5	U	5	U	5	U	4.8
1,1-DICHLOROETHANE	5	U	5	U	5	U	100000
1,2-DICHLOROETHENE	5	U	5	U	5	U	9200
CHLOROFORM	5	U	5	U	5	U	470
1,2-DICHLOROETHANE	5	U	5	U	5	U	31
2-BUTANONE	11	U	11	U	11	U	610000
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	92000
CARBON TETRACHLORIDE	5	U	5	U	5	U	22
VINYL ACETATE	11	U	11	U	11	U	1000000
BROMODICHLOROMETHANE	5	U	5	U	5	U	48
1,2-DICHLOROPROPANE	5	U	5	U	5	U	42
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	16
TRICHLOROETHENE	5	U	5	U	5	U	280
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	-
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	50
BENZENE	5	U	5	U	5	U	99
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	16
BROMOFORM	5	U	5	U	5	U	360
4-METHYL-2-PENTANONE	11	U	11	U	11	U	-
2-HEXANONE	11	U	11	U	11	U	-
TETRACHLOROETHENE	5	U	5	U	5	U	55
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	14
TOLUENE	5	U	5	U	5	U	200000
CHLOROBENZENE	5	U	5	U	5	U	20000
ETHYLBENZENE	5	U	5	U	5	U	100000
STYRENE	5	U	5	U	5	U	200000
TOTAL XYLENES	5	U	5	U	5	U	1000000

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil (ug/kg)									
SAMPLE NO.	BGSS-1-1		BGSS-1-2		MUD		RBC		
	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	CONC.		
COMPOUND									
CHLOROMETHANE	11	U	11	U	250	U	220		
BROMOMETHANE	11	U	11	U	250	U	1400		
VINYL CHLORIDE	11	U	11	U	250	U	1.5		
CHLOROETHANE	11	U	11	U	250	U	20000		
METHYLENE CHLORIDE	5	12	B	5	7	120	530	B	380
ACETONE	11	U	11	U	250	690	100000		
CARBON DISULFIDE	5	U	5	U	120	U	100000		
1,1-DICHLOROETHENE	5	U	5	U	120	U	4.8		
1,1-DICHLOROETHANE	5	U	5	U	120	U	100000		
1,2-DICHLOROETHENE	5	U	5	U	120	U	9200		
CHLOROFORM	5	U	5	U	120	270	470		
1,2-DICHLOROETHANE	5	U	5	U	120	U	31		
2-BUTANONE	11	U	11	U	250	U	610000		
1,1,1-TRICHLOROETHANE	5	U	5	U	120	U	92000		
CARBON TETRACHLORIDE	5	U	5	U	120	U	22		
VINYL ACETATE	11	U	11	U	250	U	1000000		
BROMODICHLOROMETHANE	5	U	5	U	120	52	J	48	
1,2-DICHLOROPROPANE	5	U	5	U	120	U	42		
CIS-1,3-DICHLOROPROPENE	5	U	5	U	120	U	16		
TRICHLOROETHENE	5	U	5	U	120	U	260		
DIBROMOCHLOROMETHANE	5	U	5	U	120	U	-		
1,1,2-TRICHLOROETHANE	5	U	5	U	120	U	50		
BENZENE	5	U	5	U	120	U	99		
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	120	U	18		
BROMOFORM	5	U	5	U	120	U	360		
4-METHYL-2-PENTANONE	11	U	11	U	250	U	-		
2-HEXANONE	11	U	11	U	250	U	-		
TETRACHLOROETHENE	5	U	5	U	120	U	55		
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	120	U	14		
TOLUENE	5	U	5	U	120	U	200000		
CHLOROBENZENE	5	U	5	U	120	U	20000		
ETHYLBENZENE	5	U	5	U	120	U	100000		
STYRENE	5	U	5	U	120	U	200000		
TOTAL XYLENES	5	21	5	U	120	U	1000000		

B - Analyte was found in the associated blank.

k

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit

RBC - EPA Region III Risk Based Concentration for Commercial/Industrial Soil (mg/kg)

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil QC Samples (ug/l)					
QC SAMPLE	EQBLK PP-1		EQBLK PP-2		
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	10	U	10	U	
BROMOMETHANE	10	U	10	U	
VINYL CHLORIDE	10	U	10	U	
CHLOROETHANE	10	U	10	U	
METHYLENE CHLORIDE	5	7	5	7	B
ACETONE	10	U	10	8	J
CARBON DISULFIDE	5	U	5	U	
1,1-DICHLOROETHENE	5	U	5	U	
1,1-DICHLOROETHANE	5	U	5	U	
1,2-DICHLOROETHENE	5	U	5	U	
CHLOROFORM	5	U	5	U	
1,2-DICHLOROETHANE	5	U	5	U	
2-BUTANONE	10	U	10	U	
1,1,1-TRICHLOROETHANE	5	U	5	U	
CARBON TETRACHLORIDE	5	U	5	U	
VINYL ACETATE	10	U	10	U	
BROMODICHLOROMETHANE	5	U	5	U	
1,2-DICHLOROPROPANE	5	U	5	U	
CIS-1,3-DICHLOROPROPENE	5	U	5	U	
TRICHLOROETHENE	5	U	5	U	
DIBROMOCHLOROMETHANE	5	U	5	U	
1,1,2-TRICHLOROETHANE	5	U	5	U	
BENZENE	5	U	5	U	
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	
BROMOFORM	5	U	5	U	
4-METHYL-2-PENTANONE	10	U	10	U	
2-HEXANONE	10	U	10	U	
TETRACHLOROETHENE	5	U	5	U	
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	
TOLUENE	5	U	5	U	
CHLOROBENZENE	5	U	5	U	
ETHYLBENZENE	5	U	5	U	
STYRENE	5	U	5	U	
TOTAL XYLENES	5	U	5	3	J

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil QC Samples (ug/l)

QC SAMPLE	EQBLK T-1		EQBLK H-1		EQBLK H-2		EQBLK H-3		EQBLK PP-1		EQBLK PP-2	
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.
CHLOROMETHANE	10	U	10	U	10	U	10	U	10	U	10	U
BROMOMETHANE	10	U	10	U	10	U	10	U	10	U	10	U
VINYL CHLORIDE	10	U	10	U	10	U	10	U	10	U	10	U
CHLOROETHANE	10	U	10	U	10	U	10	U	10	U	10	U
METHYLENE CHLORIDE	5	12	BX	5	21	B	5	6	B	5	7	B
ACETONE	10	150	B	10	U	10	U	10	10	10	U	8
CARBON DISULFIDE	5	1	J	5	U	5	U	5	U	5	U	U
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U
2-BUTANONE	10	U	10	U	10	U	10	U	10	U	10	U
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U
VINYL ACETATE	10	U	10	U	10	U	10	U	10	U	10	U
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U
TRANS-1,3-DICHLOROPROPE	5	U	5	U	5	U	5	U	5	U	5	U
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U
4-METHYL-2-PENTANONE	10	U	10	U	10	U	10	U	10	U	10	U
2-HEXANONE	10	U	10	U	10	U	10	U	10	U	10	U
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U
1,1,2,2-TETRACHLOROETHAN	5	U	5	U	5	U	5	U	5	U	5	U
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U
TOTAL XYLENES	5	2	J	5	U	5	U	5	U	5	U	3

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit

Table G-1 (Cont.) Summary of Analytical Data for Volatile Organics in Soil QC Samples (ug/l)

QC SAMPLE	TRPBLK 9/25/90		TRPBLK 9/25/90		TRPBLK 9/26/90		TRPBLK 9/28/90		TRPBLK 9/30/90		TRPBLK 10/3/90		TRPBLK 10/4/90	
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.
CHLOROMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
BROMOMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
VINYL CHLORIDE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
CHLOROETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
METHYLENE CHLORIDE	5	11	B	5	8	B	5	9	B	5	8	B	5	12
ACETONE	10	23	B	10	U	10	U	10	U	10	U	10	10	B
CARBON DISULFIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
2-BUTANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
VINYL ACETATE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U
4-METHYL-2-PENTANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
2-HEXANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TOTAL XYLENES	5	U	5	U	5	U	5	U	5	U	5	U	5	U

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit

Table G-2 Summary of Analytical Data for Semivolatile Organics in Soil (ug/kg)

SAMPLE NO.	TA-1-1		TA-1-2		TA-1-2-FD		TA-5-1		TA-5-2	
COMPOUND	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc
3-NITROANILINE	1700	U	1700	U	1700	U	25000	U	1700	U
ACENAPHTHENE	1000	U	300	U	350	U	5100	U	350	U
2,4-DINITROPHENOL	5100	U	1700	U	1700	U	25000	U	1700	U
4-NITROPHENOL	5100	U	1700	U	1700	U	25000	U	1700	U
DIBENZOFURAN	1000	U	300	U	350	U	5100	U	350	U
2,4-DINITROTOLUENE	1000	U	300	U	350	U	5100	U	350	U
DIETHYLPHTHALATE	1000	U	300	U	350	U	5100	U	350	U
4-CHLOROPHENYL-PHENYLETHE	1000	U	300	U	350	U	5100	U	350	U
FLUORENE	1000	U	300	U	350	U	5100	U	350	U
4-NITROANILINE	5100	U	1700	U	1700	U	25000	U	1700	U
4,6-DINITRO-2-METHYLPHENOL	5100	U	300	U	1700	U	25000	U	1700	U
N-NITROSODIPHENYLAMINE	1000	U	300	U	350	U	5100	U	350	U
4-BROMOPHENYL-PHENYLETHE	1000	U	300	U	350	U	5100	U	350	U
HEXACHLOROBENZENE	1000	U	300	U	350	U	5100	U	350	U
PENTACHLOROPHENOL	5100	U	1700	U	1700	U	5100	U	1700	U
PHENANTHRENE	1000	U	300	U	350	U	25000	U	350	U
ANTHRACENE	1000	U	300	U	350	U	5100	U	350	U
DI-N-BUTYLPHTHALATE	1000	U	300	900	350	53	5100	U	350	U
FLUORANTHENE	1000	U	300	U	350	U	5100	U	350	U
PYRENE	1000	U	300	U	350	U	5100	U	350	U
BUTYLBENZYLPHTHALATE	1000	U	300	U	350	U	5100	U	350	U
3,3'-DICHLOROBENZIDINE	2100	U	690	U	690	U	10000	U	710	U
BENZO(A)ANTHRACENE	1000	U	300	U	350	U	5100	U	350	U
CHRYSENE	1000	U	300	U	350	U	5100	U	350	U
BIS(2-ETHYLHEXYL)PHTHALATE	1000	820	300	U	350	980	5100	U	350	U
DI-N-OCTYL PHTHALATE	1000	U	300	U	350	U	5100	U	350	U
BENZO(B)FLUORANTHENE	1000	U	300	U	350	U	5100	U	350	U
BENZO(K)FLUORANTHENE	1000	U	300	U	350	U	5100	U	350	U
BENZO(A)PYRENE	1000	U	300	U	350	U	5100	U	350	U
INDENO(1,2,3-CD)PYRENE	1000	U	300	U	350	U	5100	U	350	U
DIBENZ(A,H)ANTHRACENE	1000	U	300	U	350	U	5100	U	350	U
BENZO(G,H,I)PERYLENE	1000	U	300	U	350	U	5100	U	350	U

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected.

Table G-2 Summary of Analytical Data for Semivolatile Organics in Soil (ug/Kg)

SAMPLE NO.	TA-1-1		TA-1-2		TA-1-2-FD		TA-5-1		TA-5-2	
COMPOUND	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.
PHENOL	1000	U	350	U	350	U	5100	U	350	U
BIS(2-CHLOROETHYL)ETHER	1000	U	350	U	350	U	5100	U	350	U
2-CHLOROPHENOL	1000	U	350	U	350	U	5100	U	350	U
1,3-DICHLOROBENZENE	1000	U	350	U	350	U	5100	U	350	U
1,4-DICHLOROBENZENE	1000	U	350	U	350	140 J	5100	U	350	110 J
BENZYL ALCOHOL	1000	U	350	U	350	U	5100	U	350	U
1,2-DICHLOROBENZENE	1000	U	350	U	350	U	5100	U	350	U
2-METHYLPHENOL	1000	U	350	U	350	U	5100	U	350	U
BIS(2-CHLOROISOPROPYL)ETHE	1000	U	350	U	350	U	5100	U	350	U
4-METHYLPHENOL	1000	U	350	U	350	U	5100	U	350	U
N-NITROSO-DI-N-PROPYLAMINE	1000	U	350	U	350	U	5100	U	350	U
HEXACHLOROETHANE	1000	U	350	U	350	U	5100	U	350	U
NITROBENZENE	1000	U	350	U	350	U	5100	U	350	U
ISOPHORONE	1000	U	350	U	350	U	5100	U	350	U
2-NITROPHENOL	1000	U	350	U	350	U	5100	U	350	U
2,4-DIMETHYLPHENOL	1000	U	350	U	350	U	5100	U	350	U
BENZOIC ACID	5100	U	1700	U	1700	U	25000	U	1700	U
BIS(2-CHLOROETHOXY)METHAN	1000	U	350	U	350	U	5100	U	350	U
2,4-DICHLOROPHENOL	1000	U	350	U	350	U	5100	U	350	U
1,2,4-TRICHLOROBENZENE	1000	U	350	U	350	U	5100	U	350	U
NAPHTHALENE	1000	U	350	U	350	U	5100	U	350	U
4-CHLOROANILINE	1000	U	350	U	350	U	5100	U	350	U
HEXACHLOROBUTADIENE	1000	U	350	U	350	U	5100	U	350	U
4-CHLORO-3-METHYLPHENOL	1000	U	350	U	350	U	5100	U	350	U
2-METHYLNAPHTHALENE	1000	U	350	U	350	U	5100	U	350	U
HEXACHLOROCYCLOPENTADIEN	1000	U	350	U	350	U	5100	U	350	U
2,4,6-TRICHLOROPHENOL	1000	U	350	U	350	U	5100	U	350	U
2,4,5-TRICHLOROPHENOL	5100	U	1700	U	1700	U	25000	U	1700	U
2-CHLORONAPHTHALENE	1000	U	350	U	350	U	5100	U	350	U
2-NITROANILINE	5100	U	1700	U	1700	U	25000	U	1700	U
DIMETHYL PHTHALATE	1000	U	350	U	350	U	5100	U	350	U
ACENAPHTHYLENE	1000	U	350	U	350	U	5100	U	350	U
2,6-DINITROTOLUENE	1000	U	350	U	350	U	5100	U	350	U

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected.

Table G-2 (Cont.) Summary of Analytical Data for Semivolatile Organics in Soil (ug/kg)

SAMPLE NO.	PP-3-1		PP-3-1FD		PP-3-2		PP-6-1		PP-6-2		PP-9-1		PP-9-2	
COMPOUND	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.
PHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BIS(2-CHLOROETHYL)ETHER	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2-CHLOROPHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
1,3-DICHLOROBENZENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
1,4-DICHLOROBENZENE	340	U	350	39 J	350	U	340	U	360	U	350	U	350	U
BENZYL ALCOHOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
1,2-DICHLOROBENZENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2-METHYLPHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BIS(2-CHLOROISOPROPYL)ETHE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
4-METHYLPHENOL	340	U	350	U	350	U	340	120 J	360	U	350	U	350	U
N-NITROSO-DI-N-PROPYLAMINE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
HEXACHLOROETHANE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
NITROBENZENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
ISOPHORONE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2-NITROPHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2,4-DIMETHYLPHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BENZOIC ACID	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
BIS(2-CHLOROETHOXY)METHAN	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2,4-DICHLOROPHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
1,2,4-TRICHLOROBENZENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
NAPHTHALENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
4-CHLOROANILINE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
HEXACHLOROBUTADIENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
4-CHLORO-3-METHYLPHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2-METHYLNAPHTHALENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
HEXACHLOROCYCLOPENTADIEN	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2,4,6-TRICHLOROPHENOL	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2,4,5-TRICHLOROPHENOL	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
2-CHLORONAPHTHALENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2-NITROANILINE	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
DIMETHYL PHTHALATE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
ACENAPHTHYLENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2,6-DINITROTOLUENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected



Table G-2 (cont.) Summary of Analytical Data for Semivolatile Organics in Soil (ug/kg)

SAMPLE NO.	PP-3-1		PP-3-1FD		PP-3-2		PP-6-1		PP-6-2		PP-9-1		PP-9-2	
COMPOUND	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc.	Detection Limits	Conc
3-NITROANILINE	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
ACENAPHTHENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2,4-DINITROPHENOL	1700	U	1700	U	1700	U	1800	U	1800	U	1700	U	1700	U
4-NITROPHENOL	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
DIBENZOFURAN	340	U	350	U	350	U	340	U	360	U	350	U	350	U
2,4-DINITROTOLUENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
DIETHYLPHTHALATE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
4-CHLOROPHENYL-PHENYLETHE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
FLUORENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
4-NITROANILINE	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
4,6-DINITRO-2-METHYLPHENOL	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
N-NITROSODIPHENYLAMINE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
4-BROMOPHENYL-PHENYLETHER	340	U	350	U	350	U	340	U	360	U	350	U	350	U
HEXACHLOROBENZENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
PENTACHLOROPHENOL	1700	U	1700	U	1700	U	1600	U	1800	U	1700	U	1700	U
PHENANTHRENE	340	U	350	U	350	U	340	U	360	47 J	350	U	350	U
ANTHRACENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
DI-N-BUTYLPHTHALATE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
FLUORANTHENE	340	U	350	U	350	U	340	U	360	46 J	350	U	350	U
PYRENE	340	U	350	U	350	U	340	U	360	43 J	350	U	350	U
BUTYLBENZYLPHTHALATE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
3,3'-DICHLOROBENZIDINE	690	U	690	U	710	U	680	U	730	U	690	U	690	U
BENZO(A)ANTHRACENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
CHRYSENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BIS(2-ETHYLHEXYL)PHTHALATE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
DI-N-OCTYL PHTHALATE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BENZO(B)FLUORANTHENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BENZO(K)FLUORANTHENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BENZO(A)PYRENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
INDENO(1,2,3-CD)PYRENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
DIBENZ(A,H)ANTHRACENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U
BENZO(G,H,I)PERYLENE	340	U	350	U	350	U	340	U	360	U	350	U	350	U

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected.

Table G-2 (Cont.) Summary of Analytical Data for Semivolatile Organics in Soil (ug/kg)

SAMPLE NO.	PP-12-1		PP-12-2		MUD		BGSS-2	
COMPOUND	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc
3-NITROANILINE	10000	U	1700	U	40000	U	1700	U
ACENAPHTHENE	2100	U	360	U	8200	U	350	U
2,4-DINITROPHENOL	10000	U	1700	U	40000	U	1700	U
4-NITROPHENOL	10000	U	1700	U	40000	U	1700	U
DIBENZOFURAN	2100	U	360	U	8200	U	350	U
2,4-DINITROTOLUENE	2100	U	360	U	8200	U	350	U
DIETHYLPHTHALATE	2100	U	360	U	8200	U	350	U
4-CHLOROPHENYL-PHENYLETHE	2100	U	360	U	8200	U	350	U
FLUORENE	2100	U	360	U	8200	U	350	U
4-NITROANILINE	10000	U	1700	U	40000	U	1700	U
4,6-DINITRO-2-METHYLPHENOL	10000	U	1700	U	40000	U	1700	U
N-NITROSODIPHENYLAMINE	2100	U	360	U	8200	U	350	U
4-BROMOPHENYL-PHENYLETHE	2100	U	360	U	8200	U	350	U
HEXACHLOROBENZENE	2100	U	360	U	8200	U	350	U
PENTACHLOROPHENOL	10000	U	1700	U	40000	U	1700	U
PHENANTHRENE	2100	U	360	U	8200	U	350	U
ANTHRACENE	2100	U	360	U	8200	U	350	U
DI-N-BUTYLPHTHALATE	2100	U	360	U	8200	900 J	350	U
FLUORANTHENE	2100	U	360	U	8200	U	350	U
PYRENE	2100	U	360	U	8200	U	350	U
BUTYLBENZYLPHTHALATE	2100	U	360	U	8200	U	350	U
3,3'-DICHLOOROBENZIDINE	4200	U	720	U	16000	U	700	U
BENZO(A)ANTHRACENE	2100	U	360	U	8200	U	350	U
CHRYSENE	2100	U	360	U	8200	U	350	U
BIS(2-ETHYLHEXYL)PHTHALATE	2100	U	360	U	8200	U	350	U
DI-N-OCTYL PHTHALATE	2100	U	360	U	8200	U	350	U
BENZO(B)FLUORANTHENE	2100	U	360	U	8200	U	350	U
BENZO(K)FLUORANTHENE	2100	U	360	U	8200	U	350	U
BENZO(A)PYRENE	2100	U	360	U	8200	U	350	U
INDENO(1,2,3-CD)PYRENE	2100	U	360	U	8200	U	350	U
DIBENZ(A,H)ANTHRACENE	2100	U	360	U	8200	U	350	U
BENZO(G,H,I)PERYLENE	2100	U	360	U	8200	U	350	U
	2100							

J - Estimated value that was found b s found below detection limits

U - Compound was analyzed for but not detected.

Table G-2 (Cont.) Summary of Analytical Data for Semivolatile Organics in Soil (ug/kg)

SAMPLE NO.	PP-12-1		PP-12-2		MUD		BGSS-2	
COMPOUND	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit		Detection Limit	Conc.
PHENOL	2100	410 J	360	U	8200	U	350	U
BIS(2-CHLOROETHYL)ETHER	2100	U	360	U	8200	U	350	U
2-CHLOROPHENOL	2100	U	360	U	8200	U	350	U
1,3-DICHLOROBENZENE	2100	U	360	U	8200	U	350	U
1,4-DICHLOROBENZENE	2100	U	360	U	8200	U	350	U
BENZYL ALCOHOL	2100	U	360	U	8200	U	350	U
1,2-DICHLOROBENZENE	2100	U	360	U	8200	U	350	U
2-METHYLPHENOL	2100	U	360	U	8200	U	350	U
BIS(2-CHLOROISOPROPYL)ETHE	2100	U	360	U	8200	U	350	U
4-METHYLPHENOL	2100	580 J	360	U	8200	U	350	U
N-NITROSO-DI-N-PROPYLAMINE	2100	U	360	U	8200	U	350	U
HEXACHLOROETHANE	2100	U	360	U	8200	U	350	U
NITROBENZENE	2100	U	360	U	8200	U	350	U
ISOPHORONE	2100	U	360	U	8200	U	350	U
2-NITROPHENOL	2100	U	360	U	8200	U	350	U
2,4-DIMETHYLPHENOL	2100	420 J	360	U	8200	U	350	U
BENZOIC ACID	10000	U	1700	U	40000	U	1700	U
BIS(2-CHLOROETHOXY)METHAN	2100	U	360	U	8200	U	350	U
2,4-DICHLOROPHENOL	2100	U	360	U	8200	U	350	U
1,2,4-TRICHLOROBENZENE	2100	U	360	U	8200	U	350	U
NAPHTHALENE	2100	U	360	U	8200	U	350	U
4-CHLOROANILINE	2100	U	360	U	8200	U	350	U
HEXACHLOROBUTADIENE	2100	U	360	U	8200	U	350	U
4-CHLORO-3-METHYLPHENOL	2100	U	360	U	8200	U	350	U
2-METHYLNAPHTHALENE	2100	U	360	U	8200	U	350	U
HEXACHLOROCYCLOPENTADIEN	2100	U	360	U	8200	U	350	U
2,4,6-TRICHLOROPHENOL	2100	U	360	U	8200	U	350	U
2,4,5-TRICHLOROPHENOL	10000	U	1700	U	40000	U	1700	U
2-CHLORONAPHTHALENE	2100	U	360	U	8200	U	350	U
2-NITROANILINE	10000	U	1700	U	40000	U	1700	U
DIMETHYL PHTHALATE	2100	U	360	U	8200	U	350	U
ACENAPHTHYLENE	2100	U	360	U	8200	U	350	U
2,6-DINITROTOLUENE	2100	U	360	U	8200	U	350	U

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected.

Table G-2 (Cont.) Summary of Analytical Data for Semivolatile Organics in Soil (ug/kg)

Table G-2 (Cont.) Summary of Analytical Data for Semivolatile Organics in Soil (ug/kg)															
SAMPLE NO.	HM-2-1		HM-2-2		HM-5-1		HM-5-2		HM-9-1		HM-9-2				
COMPOUND	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc	Detection Limits	Conc			
3-NITROANILINE	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U			
ACENAPHTHENE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
2,4-DINITROPHENOL	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U			
4-NITROPHENOL	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U			
DIBENZOFURAN	3500	U	720	U	690	U	330	U	1400	U	1800	U			
2,4-DINITROTOLUENE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
DIETHYLPHTHALATE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
4-CHLOROPHENYL-PHENYLETHE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
FLUORENE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
4-NITROANILINE	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U			
4,6-DINITRO-2-METHYLPHENOL	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U			
N-NITROSODIPHENYLAMINE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
4-BROMOPHENYL-PHENYLETHE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
HEXACHLOROBENZENE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
PENTACHLOROPHENOL	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U			
PHENANTHRENE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
ANTHRACENE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
DI-N-BUTYLPHTHALATE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
FLUORANTHENE	3500	360	J	720	190	J	690	85	J	330	U	1400	U		
PYRENE	3500	490	J	720	270	J	690	98	J	330	U	1400	U		
BUTYLBENZYLPHTHALATE	3500	U	720	U	690	U	330	U	1400	U	1800	U			
3,3'-DICHLOROBENZIDINE	6900	U	1400	U	1400	U	660	U	2800	U	3600	U			
BENZO(A)ANTHRACENE	3500	U	720	170	J	690	U	330	U	1400	U	1800	U		
CHRYSENE	3500	U	720	160	J	690	U	330	U	1400	U	1800	U		
BIS(2-ETHYLHEXYL)PHTHALATE	3500	820	J	720	U	690	89	J	330	U	1400	U	1800	U	
DI-N-OCTYL PHTHALATE	3500	U	720	U	690	U	330	U	1400	U	1800	U	1800	U	
BENZO(B)FLUORANTHENE	3500	U	720	110	J	690	U	330	U	1400	U	1800	U	1800	U
BENZO(K)FLUORANTHENE	3500	U	720	U	690	U	330	U	1400	U	1800	U	1800	U	
BENZO(A)PYRENE	3500	U	720	140	J	690	U	330	U	1400	U	1800	U	1800	U
INDENO(1,2,3-CD)PYRENE	3500	U	720	U	690	U	330	U	1400	U	1800	U	1800	U	
DIBENZ(A,H)ANTHRACENE	3500	U	720	U	690	U	330	U	1400	U	1800	U	1800	U	
BENZO(G,H,I)PERYLENE	3500	U	720	U	690	U	330	U	1400	U	1800	U	1800	U	

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected.

Table G-2 (Cont.) Summary of Analytical Data for Semivolatile Organics in Soil (ug/Kg)

SAMPLE NO.	HM-2-1		HM-2-2		HM-5-1		HM-5-2		HM-9-1		HM-9-2	
COMPOUND	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.	Detection Limit	Conc.
PHENOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
BIS(2-CHLOROETHYL)ETHER	3500	U	720	U	690	U	330	U	1400	U	1800	U
2-CHLOROPHENOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
1,3-DICHLOROBENZENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
1,4-DICHLOROBENZENE	3500	U	720	U	690	U	330	U	1400	140 J	1800	U
BENZYL ALCOHOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
1,2-DICHLOROBENZENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
2-METHYLPHENOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
BIS(2-CHLOROISOPROPYL)ETHE	3500	U	720	U	690	U	330	U	1400	U	1800	U
4-METHYLPHENOL	3500	650 J	720	U	690	U	330	U	1400	U	1800	U
N-NITROSO-DI-N-PROPYLAMINE	3500	U	720	U	690	U	330	U	1400	U	1800	U
HEXACHLOROETHANE	3500	U	720	U	690	U	330	U	1400	U	1800	U
NITROBENZENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
ISOPHORONE	3500	U	720	U	690	U	330	U	1400	U	1800	U
2-NITROPHENOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
2,4-DIMETHYLPHENOL	3500	3600	720	240 J	690	190 J	330	U	1400	390 J	1800	U
BENZOIC ACID	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U
BIS(2-CHLOROETHOXY)METHAN	3500	U	720	U	690	U	330	U	1400	U	1800	U
2,4-DICHLOROPHENOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
1,2,4-TRICHLOROBENZENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
NAPHTHALENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
4-CHLOROANILINE	3500	U	720	U	690	U	330	U	1400	U	1800	U
HEXACHLOROBUTADIENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
4-CHLORO-3-METHYLPHENOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
2-METHYLNAPHTHALENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
HEXACHLOROCYCLOPENTADIEN	3500	U	720	U	690	U	330	U	1400	U	1800	U
2,4,6-TRICHLOROPHENOL	3500	U	720	U	690	U	330	U	1400	U	1800	U
2,4,5-TRICHLOROPHENOL	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U
2-CHLORONAPHTHALENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
2-NITROANILINE	17000	U	3500	U	3400	U	1600	U	6700	U	8800	U
DIMETHYL PHTHALATE	3500	U	720	U	690	U	330	U	1400	U	1800	U
ACENAPHTHYLENE	3500	U	720	U	690	U	330	U	1400	U	1800	U
2,6-DINITROTOLUENE	3500	U	720	U	690	U	330	U	1400	U	1800	U

J - Estimated value that was found below detection limits.

U - Compound was analyzed for but not detected. detected.

Table G-3 Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Soil (mg/kg)									
SAMPLE NO.	TA-1-1	TA-1-2	TA-1-2-FD	TA-3-1	TA-3-2	TA-5-1	TA-5-2	SW-2	SW-3
SAMPLE DEPTH									
REFERENCE OIL STANDARD									
#2 FUEL OIL									
#4 FUEL OIL									
#5 FUEL OIL									
#6 FUEL OIL									
JET FUEL									
DIESEL FUEL									
GASOLINE									
KEROSENE									
MOTOR OIL									
COMPRESSOR OIL								700	210
MINERAL SPIRITS									
LUBE OIL	1400	96	1600						
HYDRAULIC JACK OIL									
NAPHTHA									
CREOSOTE									
ASPHALT									
TRANSMISSION FLUID									
DID NOT MATCH ANY REFERENCE STANDARDS						4400	82		
NO EVIDENCE OF HYDROCARBON CONTAMINATION IN SAMPLE				U	U				

VDEQ Soil Action Level for TPH = 100 mg/kg

U - Below Quantification Limits

Table G-3 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Soil (mg/kg)											
SAMPLE NO.	EY-2-1	EY-2-2	EY-3-1	EY-3-2	EY-4-1	EY-4-2	EY-5-1	EY-5-2	EY-5-2FD	EY-7-1	EY-7-2
SAMPLE DEPTH											
REFERENCE OIL STANDARD											
#2 FUEL OIL											
#4 FUEL OIL											
#5 FUEL OIL											
#6 FUEL OIL											
JET FUEL											
DIESEL FUEL											
GASOLINE											
KEROSENE											
MOTOR OIL											
COMPRESSOR OIL											
MINERAL SPIRITS											
LUBE OIL											
HYDRAULIC JACK OIL											
NAPHTHA											
CREOSOTE											
ASPHALT											
TRANSMISSION FLUID											
DID NOT MATCH ANY											
REFERENCE STANDARDS											
NO EVIDENCE OF HYDROCARBON											
CONTAMINATION IN SAMPLE	U	U	U	U	U	U		U	X	U	X

VDEQ Soil Action Level for TPH = 100 mg/kg

U - Below Quantification Limits

Table G-3 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Soil (mg/kg)

SAMPLE NO.	PP-2-1	PP-2-2	PP-3-1	PP-3-1FD	PP-3-2	PP-5-1	PP-5-2	PP-6-1	PP-6-2
SAMPLE DEPTH									
REFERENCE OIL STANDARD									
#2 FUEL OIL									
#4 FUEL OIL									
#5 FUEL OIL									
#6 FUEL OIL									
JET FUEL									
DIESEL FUEL									
GASOLINE									
KEROSENE									
MOTOR OIL		100							
COMPRESSOR OIL			1000	950		700		900	
MINERAL SPIRITS									
LUBE OIL	1500								
HYDRAULIC JACK OIL									
NAPHTHA									
CREOSOTE									
ASPHALT									
TRANSMISSION FLUID									
DID NOT MATCH ANY REFERENCE STANDARDS									
NO EVIDENCE OF HYDROCARBON CONTAMINATION IN SAMPLE					U		U		U

VDEQ Soil Action Level for TPH = 100 mg/kg

U - Below Quantification Limits



**Table G-3 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Soil  
(mg/kg)**

SAMPLE NO.	PP-8-1	PP-8-2	PP-9-1	PP-9-2	PP-11-2	PP-12-1	PP-12-2	PP-14-1	PP-14-2	PP-14-2FD
SAMPLE DEPTH										
REFERENCE OIL STANDARD										
#2 FUEL OIL										
#4 FUEL OIL										
#5 FUEL OIL										
#6 FUEL OIL										
JET FUEL										
DIESEL FUEL										
GASOLINE										
KEROSENE										
MOTOR OIL										
COMPRESSOR OIL	550	40				1100	170			
MINERAL SPIRITS								440		
LUBE OIL										
HYDRAULIC JACK OIL						920	63			
NAPHTHA										
CREOSOTE										
ASPHALT										
TRANSMISSION FLUID										
DID NOT MATCH ANY REFERENCE STANDARDS										
NO EVIDENCE OF HYDROCARBO CONTAMINATION IN SAMPLE			U	U	U				U	U

VDEQ Soil Action Level for TPH = 100 mg/kg

U - Below Quantification Limits

Table G-3 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Soil (mg/kg)											
SAMPLE NO.	HM-2-1	HM-2-2	HM-3-1	HM-3-2	HM-4-1	HM-4-1FD	HM-4-2	HM-5-1	HM-5-2	HM-7-1	HM-7-2
SAMPLE DEPTH											
REFERENCE OIL STANDARD											
#2 FUEL OIL											
#4 FUEL OIL											
#5 FUEL OIL											
#6 FUEL OIL											
JET FUEL											
DIESEL FUEL											
GASOLINE											
KEROSENE											
MOTOR OIL											
COMPRESSOR OIL											
MINERAL SPIRITS											
LUBE OIL											
HYDRAULIC JACK OIL	430	360	880		580						
NAPHTHA											
CREOSOTE											
ASPHALT											
TRANSMISSION FLUID											
DID NOT MATCH ANY REFERENCE STANDARDS											
NO EVIDENCE OF HYDROCARBON CONTAMINATION IN SAMPLE										U	U

VDEQ Soil Action Level for TPH = 100 mg/kg

U - Below Quantification Limits

Table G-3 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Soil (mg/kg)				
SAMPLE NO.	HM-9-1	HM-9-2	HM-10-1	HM-10-2
SAMPLE DEPTH				
REFERENCE OIL STANDARD				
#2 FUEL OIL				
#4 FUEL OIL				
#5 FUEL OIL				
#6 FUEL OIL				
JET FUEL				
DIESEL FUEL				
GASOLINE				
KEROSENE				
MOTOR OIL				
COMPRESSOR OIL		1100		2500
MINERAL SPIRITS				
LUBE OIL				
HYDRAULIC JACK OIL				
NAPHTHA				
CREOSOTE				
ASPHALT				
TRANSMISSION FLUID				
DID NOT MATCH ANY				
REFERENCE STANDARDS	X			
NO EVIDENCE OF HYDROCARBON				
CONTAMINATION IN SAMPLE			U	

VDEQ Soil Action Level for TPH = 100 mg/kg

U - Below Quantification Limits

Table G-3 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Groundwater (mg/l)							
SAMPLE NO.	GW-1-1	GW-1-2	GW-3-1	GW-3-2	GW-4-1	GW-4-2	GW-4-2FD
SAMPLE DEPTH							
REFERENCE OIL STANDARD							
#2 FUEL OIL							
#4 FUEL OIL							
#5 FUEL OIL							
#6 FUEL OIL							
JET FUEL							
DIESEL FUEL							
GASOLINE							
KEROSENE							
MOTOR OIL							
COMPRESSOR OIL							
MINERAL SPIRITS							
LUBE OIL							
HYDRAULIC JACK OIL							
NAPHTHA							
CREOSOTE							
ASPHALT							
TRANSMISSION FLUID							
DID NOT MATCH ANY							
REFERENCE STANDARDS							
NO EVIDENCE OF HYDROCARBON							
CONTAMINATION IN SAMPLE	U	U	U	U	U	U	U

NOTE: Numbers in brackets indicate estimated concentration of hydrocarbon that does not match reference standards

VDEQ standard for TPH in Groundwater is 1 ppm.

U - Below Quantification Limits

**Table G-3 (Cont.) Summary of Analytical Data for  
Total Petroleum Hydrocarbon Concentrations in Soil**

ANALYTE	Percent Solids	TPH (mg/kg)	VDEQ Action Levels (mg/kg)
SAMPLE NUMBER			
SS-1	93.1	126	100
SS-3	93	26.8 U	100
SS-3-Duplicate	93.1	55.9	100
SS-4	92.9	207	100
SS-5	81.5	67	100
SS-6	91.8	36	100
SS-7	95.1	43.1	100
SS-8	91.4	280	100
SS-9	94.2	124	100
SS-10	96	39.4	100
SS-11	96	25 U	100
SS-11-Duplicate	96.2	26.5 U	100
SS-12	93.2	40.6	100
SS-13	95	65.7	100
SS-14	95.4	25.4 U	100
SS-15	93.7	232	100
SS-16	94.7	977	100

U - Below Quantification Limits

Table G-3 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Background Soil (mg/kg)			
SAMPLE NO.	BGSS-1-1	BGSS1-2	MUD
SAMPLE DEPTH			
REFERENCE OIL STANDARD			
#2 FUEL OIL			
#4 FUEL OIL			
#5 FUEL OIL			
#6 FUEL OIL	92	74	
JET FUEL			
DIESEL FUEL			
GASOLINE			
KEROSENE			
MOTOR OIL			
COMPRESSOR OIL			
MINERAL SPIRITS			
LUBE OIL			
HYDRAULIC JACK OIL			
NAPTHA			
CREOSOTE			
ASPHALT			
TRANSMISSION FLUID			
DID NOT MATCH ANY REFERENCE STANDARDS			
NO EVIDENCE OF HYDROCARBON CONTAMINATION IN SAMPLE			U

VDEQ Soil Action Level for TPH = 100 mg/kg

U - Below Quantification Limits

**Table G-4 TCLP Organics**  
**Summary of Data for Volatile Organics (ug/l) from Soil Extracts**

SAMPLE NO.	TA-2		TA-4		TCLP STANDARDS
COMPOUND	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	
BENZENE	5	U	5	U	500
CARBON TETRACHLORIDE	5	U	5	U	500
CHLOROBENZENE	5	U	5	U	100000
CHLOROFORM	5	U	5	U	6000
1,2-DICHLOROETHANE	5	U	5	U	500
1,1-DICHLOROETHYLENE	5	U	5	U	700
METHYLETHYLKETONE	10	U	10	U	200000
TETRACHLOROETHYLENE	5	U	5	U	700
TRICHLOROETHYLENE	5	U	5	U	500
VINYL CHLORIDE	10	U	10	U	200
PYRIDINE	1000	U	1000	U	500

U - Compound was analyzed but not detected.

Table G-4 (Cont.) TCLP Organics Summary of Data for Semivolatile Organics (ug/l) from Soil Extracts					
SAMPLE NO.	TA-2		TA-4		TCLP STANDARD
COMPOUND	DETECTION LIMITS	DETECTION CONC. LIMITS	DETECTION LIMITS	DETECTION CONC.	
2,4-DINITROTOLUENE	33	U	33	U	130
HEXACHLOROBENZENE	33	U	33	U	130
HEXACHLORO-1,3-BUTADIENE	33	U	33	U	500
HEXACHLOROETHANE	33	U	33	U	3000
NITROBENZENE	33	U	33	U	2000
1,4-DICHLOROBENZENE	33	U	33	U	7500
2-METHYLPHENOL	33	U	33	U	
3-METHYLPHENOL	33	U	33	U	
4-METHYLPHENOL	33	U	33	U	
PENTACHLOROPHENOL	160	U	160	U	100000
2,4,5-TRICHLOROPHENOL	160	U	160	U	400000
2,4,6-TRICHLOROPHENOL	33	U	33	U	2000

U - Compound was analyzed for but not detected.



Table G-4 (Cont.) TCLP Organics Summary of Data for Volatile Organics (ug/l) from Soil Extracts					
SAMPLE NO.	EY-1		EY-6		TCLP STANDARD
COMPOUND	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	
BENZENE	5	U	5	U	500
CARBON TETRACHLORIDE	5	U	5	U	500
CHLOROBENZENE	5	U	5	U	100000
CHLOROFORM	5	U	5	U	6000
1,2-DICHLOROETHANE	5	U	5	U	500
1,1-DICHLOROETHYLENE	5	U	5	U	700
METHYLETHYLKETONE	10	U	10	U	200000
TETRACHLOROETHYLENE	5	U	5	U	700
TRICHLOROETHYLENE	5	U	5	U	500
VINYL CHLORIDE	10	U	10	U	200
PYRIDINE	1000	U	1000	U	500

U - Compound was analyzed but not detected.

Table G-4 (Cont.) TCLP Organics Summary of Data for Semivolatile Organics (ug/l) from Soil Extracts					
SAMPLE NO.	EY-1		EY-6		TCLP STANDARD
COMPOUND	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	
2,4-DINITROTOLUENE	33	U	33	U	130
HEXACHLOROBENZENE	33	U	33	U	130
HEXACHLORO-1,3-BUTADIENE	33	U	33	U	500
HEXACHLOROETHANE	33	U	33	U	3000
NITROBENZENE	33	U	33	U	2000
1,4-DICHLOROBENZENE	33	U	33	U	7500
2-METHYLPHENOL	33	U	33	U	
3-METHYLPHENOL	33	U	33	U	
4-METHYLPHENOL	33	U	33	U	
PENTACHLOROPHENOL	160	U	160	U	100000
2,4,5-TRICHLOROPHENOL	160	U	160	U	400000
2,4,6-TRICHLOROPHENOL	33	U	33	U	2000

U - Compound was analyzed for but not detected.

**Table G-4 (Cont.) TCLP Organics**  
**Summary of Data for Volatile Organics (ug/l) from Soil Extracts**

SAMPLE NO.	PP-1		PP-4		PP-7		PP-10		PP-13		TCLP STANDARDS
COMPOUND	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	
BENZENE	5	U	5	U	5	U	5	U	5	U	500
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	500
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	100000
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	6000
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	500
1,1-DICHLOROETHYLENE	5	U	5	U	5	U	5	U	5	U	700
METHYLETHYLKETONE	10	U	10	U	10	U	10	U	10	U	200000
TETRACHLOROETHYLENE	5	U	5	U	5	U	5	U	5	U	700
TRICHLOROETHYLENE	5	U	5	U	5	U	5	U	5	U	500
VINYL CHLORIDE	10	U	10	U	10	U	10	U	10	U	200
PYRIDINE	1000	U	1000	U	1000	U	1000	U	1000	U	500

U - Compound was analyzed but not detected.

Table G-4 (Cont.) TCLP Organics Summary of Data for Semivolatile Organics (ug/l) from Soil Extracts											
SAMPLE NO.	PP-1		PP-4		PP-7		PP-10		PP-13		TCLP STANDARD
COMPOUND	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	
2,4-DINITROTOLUENE	33	U	33	U	33	U	33	U	33	U	130
HEXACHLOROBENZENE	33	U	33	U	33	U	33	U	33	U	130
HEXACHLORO-1,3-BUTADIENE	33	U	33	U	33	U	33	U	33	U	500
HEXACHLOROETHANE	33	U	33	U	33	U	33	U	33	U	3000
NITROBENZENE	33	U	33	U	33	U	33	U	33	U	2000
1,4-DICHLOROBENZENE	33	U	33	U	33	U	33	U	33	U	7500
2-METHYLPHENOL	33	U	33	U	33	U	33	U	33	U	
3-METHYLPHENOL	33	U	33	U	33	U	33	U	33	U	
4-METHYLPHENOL	33	U	33	U	33	U	33	U	33	U	
PENTACHLOROPHENOL	160	U	160	U	160	U	160	U	160	U	100000
2,4,5-TRICHLOROPHENOL	160	U	160	U	160	U	160	U	160	U	400000
2,4,6-TRICHLOROPHENOL	33	U	33	U	33	U	33	U	33	U	2000

U - Compound was analyzed for but not detected.

Table G-4 (Cont.) TCLP Organics Summary of Data for Volatile Organics (ug/l) from Soil Extracts									
SAMPLE NO.	HM-1		HM-1FD		HM-6		HM-8		TCLP STANDARDS
COMPOUND	DETECTION LIMITS		DETECTION LIMITS		DETECTION LIMITS		DETECTION LIMITS		
	CONC.		CONC.		CONC.		CONC.		
BENZENE	5	U	5	U	5	U	5	U	500
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	500
CHLOROBENZENE	5	U	5	U	5	U	5	U	100000
CHLOROFORM	5	U	5	U	5	U	5	U	6000
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	500
1,1-DICHLOROETHYLENE	5	U	5	U	5	U	5	U	700
METHYLETHYLKETONE	10	U	10	U	10	U	10	U	200000
TETRACHLOROETHYLENE	5	6	5	U	5	8	5	U	700
TRICHLOROETHYLENE	5	U	5	U	5	U	5	U	500
VINYL CHLORIDE	10	U	10	U	10	U	10	U	200
PYRIDINE	1000	U	1000	U	1000	U	1000	U	500

U - Compound was analyzed but not detected.

**Table G-4 (Cont.) TCLP Organics**  
**Summary of Data for Semivolatile Organics (ug/l)**  
**from Soil Extracts**

SAMPLE NO.	HM-1	HM-1FD	HM-6	HM-8	TCLP STANDARDS
COMPOUND	DETECTION LIMITS	DETECTION LIMITS	DETECTION LIMITS	DETECTION LIMITS	
	CONC.	CONC.	CONC.	CONC.	
2,4-DINITROTOLUENE	33 U	33 U	33 U	33 U	130
HEXACHLOROBENZENE	33 U	33 U	33 U	33 U	130
HEXACHLORO-1,3-BUTADIEN	33 U	33 U	33 U	33 U	500
HEXACHLOROETHANE	33 U	33 U	33 U	33 U	3000
NITROBENZENE	33 U	33 U	33 U	33 U	2000
1,4-DICHLOROBENZENE	33 U	33 U	33 U	33 U	7500
2-METHYLPHENOL	33 U	33 U	33 U	33 U	
3-METHYLPHENOL	33 U	33 U	33 U	33 U	
4-METHYLPHENOL	33 180	33 75	33 U	33 U	
PENTACHLOROPHENOL	160 U	160 U	160 U	160 U	100000
2,4,5-TRICHLOROPHENOL	160 U	160 U	160 U	160 U	400000
2,4,6-TRICHLOROPHENOL	33 U	33 U	33 U	33 U	2000

U - Compound was analyzed for but not detected.

**Table G-4 (Cont.) TCLP Organics**  
**Summary of Data for Volatile Organics (ug/l) from Soil Extracts**

SAMPLE NO.	SW-1		SW-4		SW-5		TCLP STANDARD
COMPOUND	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	
BENZENE	5	U	5	U	5	U	500
CARBON TETRACHLORIDE	5	U	5	U	5	U	500
CHLOROBENZENE	5	U	5	U	5	U	100000
CHLOROFORM	5	U	5	U	5	U	6000
1,2-DICHLOROETHANE	5	U	5	U	5	U	500
1,1-DICHLOROETHYLENE	5	U	5	U	5	U	700
METHYLETHYLKETONE	10	U	10	U	10	U	200000
TETRACHLOROETHYLENE	5	U	5	U	5	U	700
TRICHLOROETHYLENE	5	U	5	U	5	U	500
VINYL CHLORIDE	10	U	10	U	10	U	200
PYRIDINE	1000	U	1000	U	1000	U	500

U - Compound was analyzed but not detected.

Table G-4 (Cont.) TCLP Organics Summary of Data for Semivolatile Organics (ug/l) from Soil Extracts							
SAMPLE NO.	SW-1		SW-4		SW-5		TCLP STANDARD
COMPOUND	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	DETECTION LIMITS	CONC.	
2,4-DINITROTOLUENE	33	U	33	U	33	U	130
HEXACHLOROBENZENE	33	U	33	U	33	U	130
HEXACHLORO-1,3-BUTADIENE	33	U	33	U	33	U	500
HEXACHLOROETHANE	33	U	33	U	33	U	3000
NITROBENZENE	33	U	33	U	33	U	2000
1,4-DICHLOROBENZENE	33	U	33	U	33	U	7500
2-METHYLPHENOL	33	U	33	U	33	U	
3-METHYLPHENOL	33	U	33	U	33	U	
4-METHYLPHENOL	33	U	33	U	33	U	
PENTACHLOROPHENOL	160	U	160	U	160	U	100000
2,4,5-TRICHLOROPHENOL	160	U	160	U	160	U	400000
2,4,6-TRICHLOROPHENOL	33	U	33	U	33	U	2000

U - Compound was analyzed for but not detected.



Table G-4 (Cont.) TCLP Organics Summary of TCLP Data for Herbicides and Pesticides (ug/l) from Soil Extracts																			
SAMPLE NO.	EY-1		EY-6		PP-1		PP-4		PP-7		PP-10		PP-13		TA-2		TA-4		TCLP STANDARDS
COMPOUND	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	
HERBICIDES																			
2,4-D	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	100	U	10000
2,4,5-TP (Silvex)	33	U	33	U	33	U	33	U	33	U	33	U	33	U	33	U	33	U	1000
PESTICIDES																			
GAMMA-BHC (Lindane)	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	400
HEPTACHLOR	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	8
HEPTACHLOR EPOXIDE	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	
ENDRIN	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	20
METHOXYCHLOR	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	10000
CHLORDANE	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	30
TOXAPHENE	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	500

U - Compound was analyzed for but not detected.

Table G-4 (Cont.) TCLP Organics Summary of TCLP Data for Herbicides and Pesticides (ug/l) from Soil Extracts															
SAMPLE NO.	SW-1		SW-4		SW-5		HM-1		HM-1-FD		HM-6		HM-8		TCLP STANDARD
COMPOUND	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	DETECTION LIMITS	DETECTION CONC.	
HERBICIDES															
2,4-D	100	U	100	U	100	U	100	U	100	U	100	U	100	U	10000
2,4,5-TP (Silvex)	33	U	33	U	33	U	33	U	33	U	33	U	33	U	1000
PESTICIDES															
GAMMA-BHC (Lindane)	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	400
HEPTACHLOR	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	8
HEPTACHLOR EPOXIDE	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	0.17	U	
ENDRIN	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	0.33	U	20
METHOXYCHLOR	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	1.7	U	10000
CHLORDANE	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	30
TOXAPHENE	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	3.3	U	500

U - Compound was analyzed for but not detected.

Table G-5 Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	TA-1-1		TA-1-2		TA-1-2FD		TA-2		TA-3-1		TA-3-2		TA-4		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM															
ANTIMONY															
ARSENIC		120 B		190 B		240 B		250		270		230		260	5000
BARIUM		189		181		221		220		186		155		214	100000
BERYLLIUM															
CADMIUM	3	U	3	3 B	3	3	3	U	3	U	3	U	3	4 B	1000
CALCIUM															
CHROMIUM	4	8 B	4	10 B	4	7 B B	4	12 B	4	17 B	4	13 B	4	9 B	5000
COBALT															
COPPER															
IRON															
LEAD	43	U	43	64 B	43	U	43	63 B	43	68 B		47 B	43	U	5000
MAGNESIUM															
MANGANESE															
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL															
POTASSIUM															
SELENIUM	53	116 B	53	69 B	53	88 B	53	75 B	53	U	53	83 B	53	U	1000
SILVER	7	U	7	U	7	7 B	7	U	7	9 B	7	U	7	7 B	5000
SODIUM															
THALLIUM															
VANADIUM															
ZINC															
CYANIDE															

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals					
SAMPLE NO.	TA-5-1		TA-5-2		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM					
ANTIMONY					
ARSENIC		220		210 B	5000
BARIUM		425		243	100000
BERYLLIUM					
CADMIUM	3	6 B	3	5 B	1000
CALCIUM					
CHROMIUM	4	16 B	4	17 B	5000
COBALT					
COPPER					
IRON					
LEAD	43	U	43	48 B	5000
MAGNESIUM					
MANGANESE					
MERCURY	0.2	U	0.2	U	200
NICKEL					
POTASSIUM					
SELENIUM	53	U	53	59 B	1000
SILVER	7	U	7	U	5000
SODIUM					
THALLIUM					
VANADIUM					
ZINC					
CYANIDE					

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	EY-1		EY-2-1		EY-2-2		EY-3-1		EY-4-1		EY-4-2		EY-5-1		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM															
ANTIMONY															
ARSENIC		73 B		82 B		107 B		105 B		173 B		174 B		185 B	5000
BARIUM		158		432		248		201		272		236		452	100000
BERYLLIUM															
CADMIUM	3	U	3	U	3	U	3	U	3	U	3	U	3	4 B	1000
CALCIUM															
CHROMIUM	4	U	4	U	4	U	4	U	4	4 B	4	4 B	4	U	5000
COBALT															
COPPER															
IRON															
LEAD	43	47 B	43	U	43	U	43	U	43	U	43	U	43	U	5000
MAGNESIUM															
MANGANESE															
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL															
POTASSIUM															
SELENIUM	53	64 B	53	86 B	53	74 B	53	84 B	53	70 B	53	60 B	53	98 B	1000
SILVER	7	U	7	U	7	U	7	U	7	U	7	U	7	U	5000
SODIUM															
THALLIUM															
VANADIUM															
ZINC															
CYANIDE															

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above  
instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	EY-5-2		EY-7-2FD		EY-6		EY-7-1		EY-7-2		TCLP STANDARDS
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM											
ANTIMONY											
ARSENIC	139 B		57	U	80 B		165 B		137 B		5000
BARIUM	223		175		154		220		196		100000
BERYLLIUM											
CADMIUM	3	U	3	U	3	U	3	U	3	U	1000
CALCIUM											
CHROMIUM	4	U	4	4 B	4	U	4	U	4	U	5000
COBALT											
COPPER											
IRON											
LEAD	43	U	43	U	43	U	43	U	43	U	5000
MAGNESIUM											
MANGANESE											
MERCURY	0.2	U	0.2	U	0.2	U	0.2	0.36 B	0.2	U	200
NICKEL											
POTASSIUM											
SELENIUM	53	U	53	U	53	62 B	53	U	53	100 B	1000
SILVER	7	U	7	U	7	U	7	U	7	U	5000
SODIUM											
THALLIUM											
VANADIUM											
ZINC											
CYANIDE											

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above  
instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)															
in Soil Extracts (ug/l)															
SAMPLE NO.	HM-1		HM-1FD		HM-2-1		HM-3-1		HM-3-2		HM-4-1		HM-4-2		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM															
ANTIMONY															
ARSENIC		95 B		117 B		104 B		191 B		134 B		159 B		118 B	5000
BARIUM		325		317		627		554		228		363		419	100000
BERYLLIUM															
CADMIUM	3	U	3	U	3	7 B	3	9 B	3	U	3	U	3	U	1000
CALCIUM															
CHROMIUM	4	U	4	U	4	4 B	4	U	4	U	4	U	4	U	5000
COBALT															
COPPER															
IRON															
LEAD	43	U	43	U	43	73 B	43	U	43	U	43	U	43	46 B	5000
MAGNESIUM															
MANGANESE															
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL															
POTASSIUM															
SELENIUM	53	U	53	66 B	53	U	53	U	53	U	53	U	53	U	1000
SILVER	7	U	7	U	7	U	7	U	7	U	7	U	7	U	5000
SODIUM															
THALLIUM															
VANADIUM															
ZINC															
CYANIDE															

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	HM-5-1		HM-6		HM-7-1		HM-7-2		HM-8		HM-9-1		HM-9-2		HM-10-1		TCLP STANDARDS
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM																	
ANTIMONY																	
ARSENIC		149 B		83 B		119 B		102 B		104 B		133 B		145 B		134 B	5000
BARIUM		328		242		342		285		333		276		337		315	100000
BERYLLIUM																	
CADMIUM	3	U	3	U	3	U	3	U	3	U	3	U	3	U	3	U	1000
CALCIUM																	
CHROMIUM	4	U	4	U	4	4 B	4	U	4	U	4	4 B	4	6 B	4	U	5000
COBALT																	
COPPER																	
IRON																	
LEAD	43	46 B	43	U	43	U	43	U	43	U	43	U	43	U	43	U	5000
MAGNESIUM																	
MANGANESE																	
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL																	
POTASSIUM																	
SELENIUM	53	U	53	71 B	53	U	53	U	53	U	53	U	53	72 B	53	65 B	1000
SILVER	7	U	7	U	7	U	7	U	7	U	7	U	7	U	7	U	5000
SODIUM																	
THALLIUM																	
VANADIUM																	
ZINC																	
CYANIDE																	

U - Analyte analyzed for but not detected

B - Analyte detected below required detection limit but above  
instrument detection limit



Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	PP-1		PP-2-1		PP-2-2		PP-3-1		PP-3-1FD		PP-4		PP-5-1		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM															
ANTIMONY															
ARSENIC		187 B		152 B		196 B		172 B		166 B		155 B		162 B	5000
BARIUM		129		228		139		282		321		200		279	100000
BERYLLIUM															
CADMIUM	3	6 B	3	5 B	3	4 B	3	4 B	3	9 B	3	7 B	3	3 B	1000
CALCIUM															
CHROMIUM	4	7	4	4	4	U	4	6	4	4 B	4	16 B	4	10 B	5000
COBALT															
COPPER															
IRON															
LEAD	43	52	43	U	43	U	43	U	43	U	43	U	43	U	5000
MAGNESIUM															
MANGANESE															
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL															
POTASSIUM															
SELENIUM	53	U	53	74 B	53	U	53	104 B	53	58	53	U	53	U	1000
SILVER	7	U	7	U	7	9 B	7	11 B	7	7 B	7	U	7	U	5000
SODIUM															
THALLIUM															
VANADIUM															
ZINC															
CYANIDE															

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above  
instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	PP-6-1		PP-6-2		PP-7		PP-8-1		PP-8-2		PP-9-1		PP-9-2		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM															
ANTIMONY															
ARSENIC		180 B		177 B		129 B	57	U		136 B		105 B		87 B	5000
BARIUM		179		79		248		202		166		222		172	100000
BERYLLIUM															
CADMIUM	3	4 B	3	4 B	3	5 B	3	3 B	3	3 B	3	5 B	3	4 B	1000
CALCIUM															
CHROMIUM	4	U	4	U	4	12 B	4	5 B	4	12 B	4	11 B	4	8 B	5000
COBALT															
COPPER															
IRON															
LEAD	43	U	43	U	43	U	43	100	43	U	43	48 B	43	U	5000
MAGNESIUM															
MANGANESE															
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL															
POTASSIUM															
SELENIUM	53	U	53	U	53	U	53	U	53	U	53	U	53	U	1000
SILVER	7	14 B	7	15 B	7	U	7	12 B	7	U	7	U	7	7 B	5000
SODIUM															
THALLIUM															
VANADIUM															
ZINC															
CYANIDE															

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above  
instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	PP-10		PP-11-1		PP-11-2		PP-12-1		PP-12-2		PP-13		PP-14-1		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM															
ANTIMONY															
ARSENIC		98 B		170 B		150 B		216 B		129 B		118 B		181 B	5000
BARIUM		144		201		118		354		257		176		199	100000
BERYLLIUM															
CADMIUM	3	3 B	3	5 B	3	5 B	3	7 B	3	4 B	3	7 B	3	6 B	1000
CALCIUM															
CHROMIUM	4	7 B	4	U	4	U	4	11 B	4	13 B	4	16 B	4	9 B	5000
COBALT															
COPPER															
IRON															
LEAD	43	48 B	43	U	43	U	43	U	43	U	43	U	43	46 B	5000
MAGNESIUM															
MANGANESE															
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL															
POTASSIUM															
SELENIUM	53	U	53	57 B	53	108 B	53	U	53	U	53	U	53	U	1000
SILVER	7	U	7	U	7	7	7	7 B	7	9 B	7	U	7	U	5000
SODIUM															
THALLIUM															
VANADIUM															
ZINC															
CYANIDE															

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above  
instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)

SAMPLE NO.	PP-14-2		PP-14-2FD		SW-1		SW-2		SW-3		SW-4		SW-5		TCLP STANDARD
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM															
ANTIMONY															
ARSENIC		136 B		86 B		148 B		121 B		132 B		120 B		290	5000
BARIUM		198		186		174		262		217		173		214	100000
BERYLLIUM															
CADMIUM	3	4 B	3	U	3	U	3	U	3	3 B	3	U	3	U	1000
CALCIUM															
CHROMIUM	4	8 B	4	11 B	4	U	4	4 B	4	U	4	4 B	4	15 B	5000
COBALT															
COPPER															
IRON															
LEAD	43	68 B	43	64 B	43	63 B	43	U	43	U	43	U	43	46 B	5000
MAGNESIUM															
MANGANESE															
MERCURY	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	200
NICKEL															
POTASSIUM															
SELENIUM	53	U	53	U	53	83 B	53	76 B	53	74 B	53	90 B	53	59 B	1000
SILVER	7	U	7	U	7	U	7	U	7	15 B	7	12 B	7	10 B	5000
SODIUM															
THALLIUM															
VANADIUM															
ZINC															
CYANIDE															

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above instrument detection limit

Table G-5 (Cont.) Summary of TCLP Data for Metals in Soil Extracts (ug/l)							
SAMPLE NO.	BGSS-1-1		BGSS-1-2		MUD		TCLP STANDARD
COMPOUN	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM							
ANTIMONY							
ARSENIC		120 B		105 B		83	5000
BARIUM		568		357		270	100000
BERYLLIUM							
CADMIUM	3	4 B	3	4 B	3	8 B	1000
CALCIUM							
CHROMIUM	4	12 B	4	14 B	4	29	5000
COBALT							
COPPER							
IRON				B			
LEAD	43	U	43	59 B	43	66 B	5000
MAGNESIUM							
MANGANESE							
MERCURY	0.2	U	0.2	U	0.2	U	200
NICKEL							
POTASSIUM							
SELENIUM	53	U	53	U	53	U	1000
SILVER	7	U	7	11	7	23	5000
SODIUM							
THALLIUM							
VANADIUM							
ZINC							
CYANIDE							

U - Analyte analyzed for but not detected

B - Analyte detected below method detection limit but above instrument detection limit

**Table G-6**  
**Results of Analysis Soil Borings**

Parameter	Moisture	Gas	Aviation	Diesel
Units	%	µg/g	µg/g	µg/g
Sample ID				
SB-1-4	6.5	< 8.56	< 8.56	< 8.74
SB-1-6	8.0	< 8.70	< 8.70	< 8.88
SB-2-4	9.0	< 8.79	< 8.79	< 8.98
SB-2-6	9.1	< 8.80	< 8.80	< 8.99
SB-3-4	8.8	< 8.77	< 8.77	< 8.96
SB-3-6	8.8	< 8.77	< 8.77	< 8.96
SB-4-4	9.7	< 8.86	< 8.86	< 9.05
SB-4-6	10.0	< 8.89	< 8.89	< 9.08
SB-5-4	8.8	< 8.77	< 8.77	28.7
SB-5-6	10.1	< 8.90	< 8.90	17.8
SB-6-4	8.9	< 8.78	< 8.78	47.1
SB-6-6	9.3	< 8.82	< 8.82	16.2
SB-7-4	7.6	< 8.66	< 8.66	< 8.84
SB-7-6	9.1	< 8.80	< 8.80	< 8.99
SB-8-4	10.0	< 8.89	< 8.89	< 9.08
SB-8-6	11.1	< 9.00	< 9.00	< 9.19

Table G-7 Summary of Analytical Data for Volatile Organics in Groundwater (ug/L)

SAMPLE NO.	SW-1-1		SW-1-1FD		SW-1-2		SW-2-1		SW-2-2		SW-3-1		VDEQ STANDARD(1)
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	250	U	50	U	250	U	500	U	500	U	10	U	
BROMOMETHANE	250	U	50	U	250	U	500	U	500	U	10	U	
VINYL CHLORIDE	250	U	50	U	250	U	500	U	500	U	10	U	
CHLOROETHANE	250	U	50	U	250	U	500	U	500	U	10	U	
METHYLENE CHLORIDE	125	540 B	25	82 B	125	370 B	250	780 B	250	780 B	5	11 B	N/A
ACETONE	250	1300	50	150	250	830	500	960	500	920	9	12 B	N/A
CARBON DISULFIDE	120	U	25	U	120	U	250	U	250	U	5	U	
1,1-DICHLOROETHENE	120	U	25	33	120	97 J	250	140 J	250	U	5	U	N/A
1,1-DICHLOROETHANE	120	290	25	240	120	210	250	520	250	540	5	U	99
1,2-DICHLOROETHENE	120	230	25	130	120	150	250	430	250	400	5	U	N/A
CHLOROFORM	120	U	25	U	120	U	250	U	250	U	5	1 J	470
1,2-DICHLOROETHANE	120	U	25	U	120	U	250	U	250	U	5	U	
2-BUTANONE	250	U	50	U	250	U	500	U	500	U	10	U	
1,1,1-TRICHLOROETHANE	120	1100	25	660	120	690	250	390	250	270	5	U	170000
CARBON TETRACHLORIDE	120	120 J	25	72	120	84 J	250	U	250	U	5	U	4.5
VINYL ACETATE	250	U	50	U	250	U	500	U	500	U	10	U	
BROMODICHLOROMETHANE	120	120 J	25	U	120	120 J	250	U	250	U	5	U	N/A
1,2-DICHLOROPROPANE	120	U	25	U	120	U	250	U	250	U	5	U	
CIS-1,3-DICHLOROPROPENE	120	U	25	U	120	U	250	U	250	U	5	U	
TRICHLOROETHENE	120	66 J	25	36	120	34 J	250	560	250	490	5	U	80.7
DIBROMOCHLOROMETHANE	120	U	25	U	120	U	250	U	250	U	5	U	
1,1,2-TRICHLOROETHANE	120	U	25	U	120	U	250	U	250	U	5	U	
BENZENE	120	U	25	U	120	U	250	U	250	U	5	U	
TRANS-1,3-DICHLOROPROPEN	120	U	25	U	120	U	250	U	250	U	5	U	
BROMOFORM	120	U	25	U	120	U	250	U	250	U	5	U	
4-METHYL-2-PENTANONE	250	U	50	U	250	U	500	U	500	U	10	U	
2-HEXANONE	250	U	50	U	250	U	500	U	500	U	10	U	
TETRACHLOROETHENE	120	220	25	170	120	180	250	4800	250	3700	5	U	3519
1,1,2,2-TETRACHLOROETHANE	120	U	25	U	120	U	250	U	250	U	5	U	
TOLUENE	120	U	25	U	120	U	250	U	250	U	5	U	
CHLOROBENZENE	120	U	25	U	120	U	250	U	250	U	5	U	
ETHYLBENZENE	120	U	25	U	120	U	250	U	250	U	5	U	
STYRENE	120	U	25	U	120	U	250	U	250	U	5	U	
TOTAL XYLENES	120	U	25	U	120	U	250	U	250	U	5	U	

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

J - Estimated value that was found below detection limits.

1 - Virginia Department of Environmental Quality Standard for Surface Water

Table G-7 (Cont.) Summary of Analytical Data for Volatile Organics in Groundwater (ug/L)

SAMPLE NO.	SW-3-2		SW-3-2FD		SW-4-1		SW-4-2		SW-5-1		SW-5-2		VDEQ STANDARD(1)
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	
BROMOMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	
VINYL CHLORIDE	10	U	10	U	10	U	10	U	10	U	10	U	
CHLOROETHANE	10	U	10	U	10	U	10	U	10	U	10	U	
METHYLENE CHLORIDE	5	5 B	5	9	5	9	5	12 B	5	4 BJ	5	13 B	N/A
ACETONE	9	9 BJ	9	19	10	7 J	12	9 BJ	10	71 B	10	68 B	N/A
CARBON DISULFIDE	5	U	5	1 J	5	U	5	U	5	U	5	U	
1,1-DICHLOROETHENE	5	U	5	U	5	28	5	41	5	U	5	1 J	N/A
1,1-DICHLOROETHANE	5	U	5	U	5	13	5	21	5	U	5	U	99
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	N/A
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	470
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	
2-BUTANONE	10	U	10	U	10	U	10	U	10	U	10	U	
1,1,1-TRICHLOROETHANE	5	U	5	U	5	3 J	5	3 J	5	U	5	U	170000
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	4.5
VINYL ACETATE	10	U	10	U	10	U	10	U	10	U	10	U	
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	N/A
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	
TRICHLOROETHENE	5	6	5	3 J	5	9	5	10	5	2 J	5	U	80.7
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U	
TRANS-1,3-DICHLOROPROPEN	5	U	5	U	5	U	5	U	5	U	5	U	
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	
4-METHYL-2-PENTANONE	10	U	10	U	10	U	10	U	10	U	10	U	
2-HEXANONE	10	U	10	U	10	U	10	U	10	U	10	U	
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	5	3 J	5	U	3519
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	
TOTAL XYLENES	5	U	5	U	5	U	5	U	5	U	5	U	

B - Analyte was found in the associated blank.

U - Compound was analyzed for but not detected.

J - Estimated value that was found below detection limits.

1 - Virginia Department of Environmental Quality Standard for Surface Water



Table G-7 (Cont.) Summary of Analytical Data for Volatile Organics in Groundwater (ug/L)

SAMPLE NO.	SW-6-1		SW-6-2		SW-7-1		SW-7-2		BGSW-8-1		BGSW-8-2		VDEQ STANDARD(1)
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	10	U	500	U	10	U	10	U	10	U	100	U	
BROMOMETHANE	10	U	500	U	10	U	10	U	10	U	100	U	
VINYL CHLORIDE	10	U	500	U	10	U	10	U	10	U	100	U	
CHLOROETHANE	10	U	500	U	10	U	10	U	10	U	100	U	
METHYLENE CHLORIDE	5	5	250	680	5	10	5	8	5	36	50	41	BJ
ACETONE	10	U	500	460	10	9	10	78	10	U	100	U	N/A
CARBON DISULFIDE	5	U	250	U	5	U	5	U	5	U	50	U	
1,1-DICHLOROETHENE	5	13	250	U	5	U	5	U	5	6	50	4	J
1,1-DICHLOROETHANE	5	16	250	U	5	U	5	U	5	U	50	U	99
1,2-DICHLOROETHENE	5	50	250	120	5	U	5	U	5	U	50	U	N/A
CHLOROFORM	5	U	250	U	5	U	5	U	5	U	50	U	470
1,2-DICHLOROETHANE	5	U	250	U	5	U	5	U	5	U	50	U	
2-BUTANONE	10	U	500	U	10	U	10	U	10	U	100	U	
1,1,1-TRICHLOROETHANE	5	1	250	U	5	U	5	U	5	U	50	U	170000
CARBON TETRACHLORIDE	5	U	250	U	5	U	5	U	5	U	50	U	4.5
VINYL ACETATE	10	U	500	U	10	U	10	U	10	U	100	U	
BROMODICHLOROMETHANE	5	U	250	U	5	U	5	U	5	U	50	U	N/A
1,2-DICHLOROPROPANE	5	U	250	U	5	U	5	U	5	U	50	U	
CIS-1,3-DICHLOROPROPENE	5	U	250	U	5	U	5	U	5	U	50	U	
TRICHLOROETHENE	5	47	250	U	5	U	5	U	5	U	50	U	80.7
DIBROMOCHLOROMETHANE	5	U	250	U	5	U	5	U	5	U	50	U	
1,1,2-TRICHLOROETHANE	5	U	250	U	5	U	5	U	5	U	50	U	
BENZENE	5	U	250	U	5	U	5	U	5	U	50	U	
TRANS-1,3-DICHLOROPROPEN	5	U	250	U	5	U	5	U	5	U	50	U	
BROMOFORM	5	U	250	U	5	U	5	U	5	U	50	U	
4-METHYL-2-PENTANONE	10	U	500	U	10	U	10	U	10	U	100	U	
2-HEXANONE	10	U	500	U	10	U	10	U	10	U	100	U	
TETRACHLOROETHENE	5	3	250	91	5	U	5	U	5	U	50	U	3519
1,1,2,2-TETRACHLOROETHANE	5	U	250	U	5	U	5	U	5	U	50	U	
TOLUENE	5	U	250	U	5	U	5	U	5	U	50	U	
CHLOROBENZENE	5	U	250	U	5	U	5	U	5	U	50	U	
ETHYLBENZENE	5	U	250	U	5	U	5	U	5	U	50	U	
STYRENE	5	U	250	U	5	U	5	U	5	U	50	U	
TOTAL XYLENES	5	U	250	U	5	U	5	U	5	U	50	U	

B - Analyte was found in the associated blank.

U - Compound was analyzed for but not detected.

J - Estimated value that was found below detection limits.

1 - Virginia Department of Environmental Quality Standard for Surface Water

Table G-7 (Cont.) Summary of Analytical Data for Volatile Organics in Groundwater (ug/L)

SAMPLE NO.	GW-3-2		GW-4-1		GW-4-2		GW-4-2FD		VDEQ STANDARD(1)
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	10	U	10	U	10	U	10	U	
BROMOMETHANE	10	U	10	U	10	U	10	U	
VINYL CHLORIDE	10	U	10	U	10	U	10	U	
CHLOROETHANE	10	U	10	U	10	U	10	U	
METHYLENE CHLORIDE	5	U	5	U	5	U	5	U	N/A
ACETONE	10	230	10	170	10	200	10	510	N/A
CARBON DISULFIDE	5	6	5	1	5	7	5	1	
1,1-DICHLOROETHENE	5	U	5	U	5	U	5	U	N/A
1,1-DICHLOROETHANE	5	2	5	U	5	U	5	U	99
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	N/A
CHLOROFORM	5	U	5	U	5	U	5	U	470
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	
2-BUTANONE	10	U	10	U	10	U	10	U	
1,1,1-TRICHLOROETHANE	5	3	5	U	5	U	5	U	170000
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	4.5
VINYL ACETATE	10	U	10	U	10	U	10	U	
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	N/A
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	
TRICHLOROETHENE	5	U	5	U	5	U	5	U	80.7
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	
BENZENE	5	U	5	U	5	U	5	U	
TRANS-1,3-DICHLOROPROPEN	5	U	5	U	5	U	5	U	
BROMOFORM	5	U	5	U	5	U	5	U	
4-METHYL-2-PENTANONE	10	U	10	U	10	U	10	U	
2-HEXANONE	10	U	10	U	10	U	10	U	
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	3519
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	
TOLUENE	5	U	5	U	5	U	5	U	
CHLOROBENZENE	5	U	5	U	5	U	5	U	
ETHYLBENZENE	5	U	5	U	5	U	5	U	
STYRENE	5	U	5	U	5	U	5	U	
TOTAL XYLENES	5	U	5	U	5	U	5	U	

B - Analyte was found in the associated blank.

U - Compound was analyzed for but not detected

J - Estimated value

below detection limit

1 - Virginia Department of Environmental Quality Standard for Surface Water

Table G-7 (Cont.) Summary of Analytical Data for Volatile Organics in Groundwater (ug/L)

SAMPLE NO.	BGDW-2		DW-1		GW-1-1		GW-1-2		GW-3-1		VDEQ STANDARD(1)
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	10	U	10	U	25	U	10	U	10	U	
BROMOMETHANE	10	U	10	U	25	U	10	U	10	U	
VINYL CHLORIDE	10	U	10	U	25	34	10	U	10	U	
CHLOROETHANE	10	U	10	U	25	U	10	U	10	U	
METHYLENE CHLORIDE	5	27	5	8	12	U	5	U	5	U	N/A
ACETONE	10	160	10	U	25	110	10	7	10	300	BE
CARBON DISULFIDE	5	U	5	U	12	U	5	U	5	U	N/A
1,1-DICHLOROETHENE	5	3	5	U	12	U	5	U	5	U	N/A
1,1-DICHLOROETHANE	5	U	5	3	12	21	5	U	5	2	J
1,2-DICHLOROETHENE	5	U	5	U	12	500	5	U	5	U	N/A
CHLOROFORM	5	19	5	60	12	U	5	U	5	U	470
1,2-DICHLOROETHANE	5	U	5	U	12	U	5	U	5	U	
2-BUTANONE	10	U	10	U	25	U	10	U	10	U	
1,1,1-TRICHLOROETHANE	5	U	5	3	12	U	5	U	5	4	J
CARBON TETRACHLORIDE	5	U	5	U	12	U	5	U	5	U	170000
VINYL ACETATE	10	U	10	U	25	U	10	U	10	U	4.5
BROMODICHLOROMETHANE	5	U	5	4	12	U	5	U	5	U	N/A
1,2-DICHLOROPROPANE	5	U	5	U	12	U	5	U	5	U	
CIS-1,3-DICHLOROPROPENE	5	U	5	U	12	U	5	U	5	U	
TRICHLOROETHENE	5	U	5	2	12	39	5	U	5	U	80.7
DIBROMOCHLOROMETHANE	5	U	5	U	12	U	5	U	5	U	
1,1,2-TRICHLOROETHANE	5	U	5	U	12	U	5	U	5	U	
BENZENE	5	U	5	U	12	U	5	U	5	U	
TRANS-1,3-DICHLOROPROPEN	5	U	5	U	12	U	5	U	5	U	
BROMOFORM	5	U	5	U	12	U	5	U	5	U	
4-METHYL-2-PENTANONE	10	U	10	U	25	U	10	U	10	U	
2-HEXANONE	10	U	10	U	25	U	10	U	10	U	
TETRACHLOROETHENE	5	U	5	3	12	14	5	U	5	U	3519
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	12	U	5	U	5	U	
TOLUENE	5	U	5	U	12	U	5	U	5	U	
CHLOROBENZENE	5	U	5	U	12	U	5	U	5	U	
ETHYLBENZENE	5	U	5	U	12	U	5	U	5	U	
STYRENE	5	U	5	U	12	U	5	U	5	U	
TOTAL XYLENES	5	U	5	U	12	U	5	U	5	U	

B - Analyte was found in the associated blank.

U - Compound was analyzed for but not detected

J - Estimated value

below detection limit

1 - Virginia Department of Environmental Quality Standard for Surface Water

Table G-7 (Cont.) Summary of Analytical Data for Volatile Organics in Water QC Samples (ug/l)

QC SAMPLE	TRPBLK 10/10/90		TRPBLK 10/29/90		TRPBLK 10/30/90		TRPBLK 10/30/90		EQBLK 11/31/91		EQBLK 10/10/90		EQBLK 11/29/91	
COMPOUND	DETECTION LIMIT (ug/l)	CONC. (ug/l)	DETECTION LIMIT (ug/l)	CONC. (ug/l)	DETECTION LIMIT (ug/l)	CONC. (ug/l)	DETECTION LIMIT (ug/l)	CONC. (ug/l)	DETECTION LIMIT (ug/l)	CONC. (ug/l)	DETECTION LIMIT (ug/l)	CONC. (ug/l)	DETECTION LIMIT (ug/l)	CONC. (ug/l)
CHLOROMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
BROMOMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
VINYL CHLORIDE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
CHLOROETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
METHYLENE CHLORIDE	5	14	B	5	18	B	5	25	B	5	17	B	5	9
ACETONE	10	12	B	10	18	B	10	45	B	10	42	B	10	63
CARBON DISULFIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	2
1,1-DICHLOROETHENE	5	U	5	U	5	4	J	5	U	5	U	5	U	5
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
2-BUTANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	1
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
VINYL ACETATE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U
4-METHYL-2-PENTANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
2-HEXANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U
TOTAL XYLENES	5	U	5	U	5	U	5	U	5	U	5	1	J	5

Note: Conc - Concentration

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit

Table G-7 (Cont.) Summary of Analytical Data for Volatile Organics in Water GC Samples (ug/l)

Table G-7 (Cont.) Summary of Analytical Data for Volatile Organics in Water QC Samples (ug/l)															
QC SAMPLE	TRPBLK 10/10/90		TRPBLK 10/29/90		TRPBLK 10/30/90		TRPBLK 1/29/91		EQBLK 10/31/90		EQBLK 10/10/90		EQBLK 1/29/91		
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
CHLOROMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
BROMOMETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
VINYL CHLORIDE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
CHLOROETHANE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
METHYLENE CHLORIDE	5	14	B	5	18	B	5	25	B	5	17	B	5	9	
ACETONE	10	12	B	10	18	B	10	45	B	10	42	B	10	63	
CARBON DISULFIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	2	
1,1-DICHLOROETHENE	5	U	5	U	5	4	J	5	U	5	U	5	U	5	
1,1-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
1,2-DICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
CHLOROFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
1,2-DICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
2-BUTANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
1,1,1-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	1	
CARBON TETRACHLORIDE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
VINYL ACETATE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
BROMODICHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
1,2-DICHLOROPROPANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
CIS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
TRICHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
DIBROMOCHLOROMETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
1,1,2-TRICHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
BENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
TRANS-1,3-DICHLOROPROPENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
BROMOFORM	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
4-METHYL-2-PENTANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
2-HEXANONE	10	U	10	U	10	U	10	U	10	U	10	U	10	U	
TETRACHLOROETHENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
1,1,2,2-TETRACHLOROETHANE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
TOLUENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
CHLOROBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
ETHYLBENZENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
STYRENE	5	U	5	U	5	U	5	U	5	U	5	U	5	U	
TOTAL XYLENES	5	U	5	U	5	U	5	U	5	U	5	1	J	5	

B - Analyte was found in the associated blank.

E - Analyte concentrations exceeded the calibration range of the GC/MS instrument.

U - Compound analyzed for but not detected

J - Estimated concentration below detection limit

TABLE G-8  
VOLATILE ORGANIC COMPOUND ANALYSIS

WELL PARAMETER (µg/L)	DW-5-D	SW-9-S	SW-9-D	DW-6-D	SW-10-S	SW-10-D	DW-7-D	DW-8-S	DW-8-D	DW-4-D	DW-3-D	FD-1	FD-2	EQPBLK	FLDBLK	TRPBLK
1,1-DICHLOROETHANE	<1.00	<1.00	<1.00	<1.00	2.5	2.82	1.07	<1.00	<1.00	<1.00	21.9	1.01	<1.00	<1.00	<1.00	<1.00
1,2-DICHLOROETHANE	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<10.00	<1.00	<1.00	<1.00	<1.00	<1.00
TETRACHLOROETHENE	<1.00	10.5	3.56	<1.00	<1.00	1.25	1.17	68.4	31.8	<1.00	7.86	9.24	18.0	<1.00	<1.00	<1.00
TRICHLOROETHENE	<1.00	10.00	3.03	<1.00	4.51	22.4	37.3	10.6	6.45	<1.00	11.2	9.99	5.23	<1.00	<1.00	<1.00

Note: FD - Field Duplicate  
EQPBLK - Equipment Blank  
FLDBLK - Field Blank  
TRPBLK - Trip Blank

**Table G-9 Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Groundwater (mg/l)**

SAMPLE NO.	SW-1-1	SW-1-1FD	SW-1-2	SW-2-1	SW-2-2	SW-3-1	SW-3-2	SW-3-2FD	SW-4-1
SAMPLE DEPTH									
REFERENCE OIL STANDARD									
#2 FUEL OIL									
#4 FUEL OIL									
#5 FUEL OIL									
#6 FUEL OIL									
JET FUEL									
DIESEL FUEL									
GASOLINE									
KEROSENE									
MOTOR OIL									
COMPRESSOR OIL									
MINERAL SPIRITS									
LUBE OIL									
HYDRAULIC JACK OIL									
NAPHTHA									
CREOSOTE									
ASPHALT									
TRANSMISSION FLUID									
DID NOT MATCH ANY									
REFERENCE STANDARDS	(<1)	(<1)	(1-5)						
NO EVIDENCE OF HYDROCARBON									
CONTAMINATION IN SAMPLE				U	U	U	U	U	U

NOTE: Numbers in brackets indicate estimated concentration of hydrocarbon that does not match reference standards  
 U - Below Quantification Limits

Table G-9 (Cont.) Summary of Analytical Data for Total Petroleum Hydrocarbon Concentrations in Groundwater (ppm) (mg/l)								
SAMPLE NO.	SW-4-2	SW-5-1	SW-5-2	SW-6-1	SW-6-2	SW-7-1	SW-7-2	BGSW-8-1 BGSW-8-2
SAMPLE DEPTH								
REFERENCE OIL STANDARD								
#2 FUEL OIL								
#4 FUEL OIL								
#5 FUEL OIL								
#6 FUEL OIL								
JET FUEL								
DIESEL FUEL								
GASOLINE								
KEROSENE								
MOTOR OIL								
COMPRESSOR OIL								
MINERAL SPIRITS								
LUBE OIL								
HYDRAULIC JACK OIL								
NAPHTHA								
CREOSOTE								
ASPHALT								
TRANSMISSION FLUID								
DID NOT MATCH ANY								
REFERENCE STANDARDS		(<1)	(<1)	(<1)	(<1)	(1-5)	(<1)	(<1)
NO EVIDENCE OF HYDROCARBON								
CONTAMINATION IN SAMPLE	U							

NOTE: Numbers in brackets indicate estimated concentration of hydrocarbon that does not match reference standards  
U - Below Quantification Limits



Table G-10 Summary of Total Priority Pollutant Metals Data in Groundwater (ug/l)

SAMPLE NO.	SW-1-2		SW-2-2		SW-3-2		SW-3-2FD		SW-4-2		SW-4		SW-5-2		BGSW-8-1		VDEQ STANDARDS
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM	52	U	52	U	52	U	52	U	52	U			52	97 B	52	U	
ANTIMONY		7.8		171		3.8 B		4.6 B		14.8		120 B		337		11.8 b B	50
ARSENIC												173					1000
BARIUM		3 B		6 B		2 B		2 B		4 B				33		4 B	
BERYLLIUM	3	U	3	8 B	3	U	3	U	3	15	3	U	3	96	3	U	0.4
CADMIUM																	
CALCIUM	4	15 B	4	281	4	9 B	4	14 B	4	206	4	4 B	4	1120	4	26	50
CHROMIUM																	
COBALT		4 B		75	4	U	4	5 B	4	55			4	261	4	11	1000
COPPER																	
IRON	43	4.5 B	43	116	43	1.8 B	43	2.5 B	43	102	43	U	43	516	43	15 B	50
LEAD																	
MAGNESIUM																	
MANGANESE	0.2	U	0.2	0.22 B	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.2	U	0.05
MERCURY		21 B		95	11	U		11 B		87				472		12 B	
NICKEL																	
POTASSIUM	2	U	10	U	2	U	2	U	10	U	53	90 B	10	U	2	U	10
SELENIUM	7	U	7	U	7	U	7	U	7	U	7	12 B	7	U	7		
SILVER																	
SODIUM	3	U	3	U	3	U	3	U	3	U			3	U	3	U	270
THALLIUM																	
VANADIUM		33		354		11		17		416				1580		45	50
ZINC																	5
CYANIDE																	

U - Analyte analyzed for but not detected

B - Detected above Instrument detection limit  
but below required method detection limit

FD - Field Duplicate

VDEQ Standards - Virginia Department of Environmental Quality Groundwater Standards

Table G-10 (Cont.) Summary of Total Priority Pollutant Metals Data in Groundwater (ug/l)

SAMPLE NO.	GW-1-2		GW-3-2		GW-4-2		GW-4-2FD		VDEQ STANDARDS
COMPOUND	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	DETECTION LIMIT	CONC.	
ALUMINUM									
ANTIMONY	33		27		41		42 B		
ARSENIC	20.3		14.7		7.5 B		7.6 B		50
BARIUM									1000
BERYLLIUM	5		4 B		4 B		4 B		
CADMIUM	3	U	3	U	3	8	3	9	0.4
CALCIUM									
CHROMIUM	4	18	4	22	4	63 B	4	120	50
COBALT									
COPPER		11 B		9 B	4	23 B	4	31	1000
IRON									
LEAD	43	17.8 B	43	26.9 B	43	19.3 B	43	46.7	50
MAGNESIUM									
MANGANESE									
MERCURY	0.2	U	0.2	U	0.2	0.3	0.2	0.38	0.05
NICKEL		10 B		15 B		31 B		53	
POTASSIUM									
SELENIUM	2	U	1	U	5	U	5	U	10
SILVER	4	U	4	U	4	U	4	4 B	
SODIUM									270
THALLIUM	2	U	1	U	1	U	1	U	
VANADIUM									
ZINC		27		42		101		138	50
CYANIDE									5

U - Analyte analyzed for but not detected

B - Detected above Instrument detection limit  
but below required method detection limit

FD - Field Duplicate

VDEQ Standards - Virginia Department of Environmental Quality Groundwater Standards

TABLE G-11 PRIMARY POLLUTANT METALS (ug/l)																		
PARAMETER	WELL NUMBER	SW-2	SW-2(F)	SW-5	SW-5(F)	SW-8	SW-8(F)	DW-1	DW-1(F)	DW-2	DW-2(F)	FD	FD(F)	SURFW	SURFW (F)	EQUIPRNS	EQUIPRNS	FLDBLK
MERCURY		<0.050	<0.050	<0.050	0.140	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
ARSENIC		10.9	7.0	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
LEAD		<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	1.6	1.5	<1.5	<1.5	<1.5
SELENIUM		<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
THALLIUM		<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
CADMIUM		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.2	0.5	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
SILVER		<2.70	<2.70	<2.70	<2.70	<2.70	8.53	4.65	<2.70	<2.70	<2.70	<2.70	<2.70	<2.70	<2.70	22.5	4.21	<2.70
BERYLLIUM		<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60	<1.60
CHROMIUM		12.3	<5.30	8.80	<5.30	11.5	8.81	<5.30	<5.30	<5.30	6.16	7.03	7.92	<5.30	<5.30	<5.30	<5.30	<5.30
COPPER		<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20	<4.20
NICKEL		<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2	<12.2
ANTIMONY		47.8	52.1	40.4	48.3	52.2	41.3	51.2	41.2	47.7	48.0	51.2	51.2	322	347	16.6	20.0	16.5
ZINC		4.52	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	4.12	4.11	7.25

Notes:

F - Filtered Sample  
 FD - Field Duplicate  
 EQUIPRNS - Equipment Blank  
 FLDBLK - Field Blank

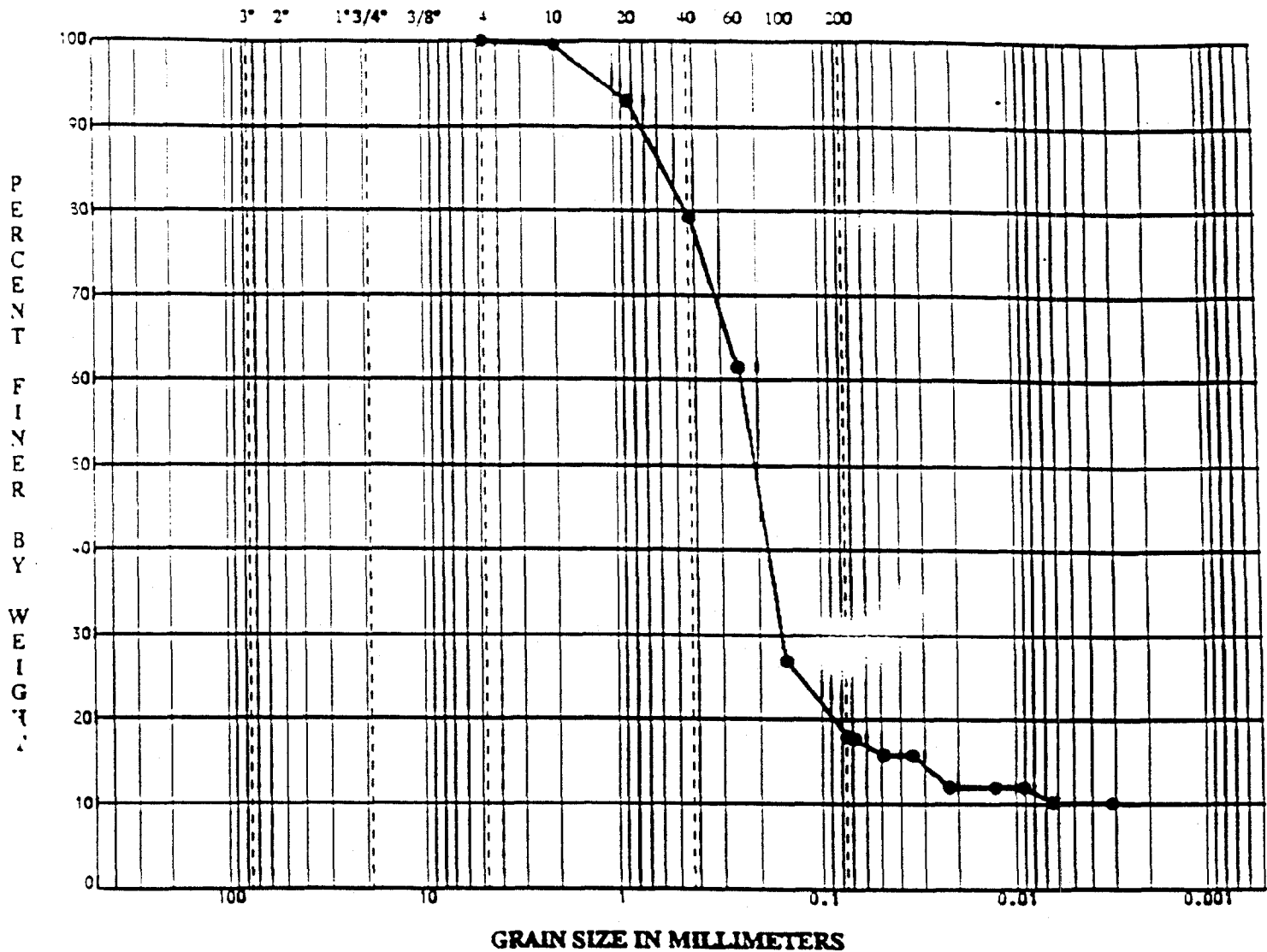
TABLE G-12 SEDIMENT SAMPLES RESULTS OF ANALYSIS					
SAMPLE ANALYSIS	SD-1	SD-2	EQIPBLK	FLDBLK	TRPBLK
CYANIDE (ug/g)	<0.3	<0.3	<0.3	<0.3	
ALUMINUM (mg/kg)	4760	1580	<40	<40	
ANTIMONY (mg/kg)	10	<5.4	<50	<50	
ARSENIC (mg/kg)	2.07	5.64	<2	<2	
BARIUM (mg/kg)	68.5	24.2	<25	<25	
BERYLLIUM (mg/kg)	<0.525	<0.525	<5	<5	
CADMIUM (mg/kg)	1.37	0.709	<5	<5	
CALCIUM (mg/kg)	2910	64500	<100	<100	
CHROMIUM (mg/kg)	32.4	13.1	<5	<5	
COBALT (mg/kg)	12.8	2.19	<20	<20	
COPPER (mg/kg)	120	23	<5	<5	
IRON (mg/kg)	14800	26400	<45	<45	
LEAD (mg/kg)	105	350	1.8	<1.5	
MAGNESIUM (mg/kg)	4000	3220	<0.05	<0.05	
MANGANESE (mg/kg)	138	322	<2.5	<2.5	
MERCURY (mg/kg)	0.398	0.319	<0.18	<0.18	
NICKEL (mg/kg)	9.18	5.41	<10	<10	
POTASSIUM (mg/kg)	1340	454	<550	<550	
SELENIUM (mg/kg)	<0.262	<0.273	<2.5	<2.5	
SILVER (mg/kg)	0.604	<0.563	<5	<5	
SODIUM (mg/kg)	230	587	161	231	
THALLIUM (mg/kg)	<0.262	<0.273	<2.5	<2.5	
VANADIUM (mg/kg)	60.6	54.5	<5	<5	
ZINC (mg/kg)	225	60.9	<30	<30	
ALDRIN (ug/kg)	<0.707	<0.729	<0.005	<0.005	
BHC, A (ug/kg)	<0.707	<0.729	<0.005	<0.005	
BHC, B (ug/kg)	<0.707	<0.729	<0.005	<0.005	
BHC, D (ug/kg)	<0.707	<0.729	<0.005	<0.005	
BHC, G (LINDANE) (ug/kg)	<0.707	<0.729	<0.005	<0.005	
GAMMA-CHLORDANE (ug/kg)	17600	172	<0.025	<0.025	
ALPHA-CHLORDANE (ug/kg)	15900	117	<0.025	<0.025	
DDD,PP* (ug/kg)	653	<0.729	<0.005	<0.005	
DDE,PP* (ug/kg)	369	8.11	<0.005	<0.005	
DDT,PP* (ug/kg)	<0.707	<0.729	<0.005	<0.005	
DIELDRIN (ug/kg)	<0.707	<0.729	<0.005	<0.005	
ENDOSULFAN, A (ug/kg)	<0.707	<0.729	<0.005	<0.005	
ENDOSULFAN, B (ug/kg)	<0.707	<0.729	<0.005	<0.005	
ENDOSULFAN SULFATE (ug/kg)	<0.707	<0.729	<0.005	<0.005	
ENDRIN (ug/kg)	<0.707	<0.729	<0.005	<0.005	
ENDRIN KETONE (ug/kg)	<28.3	<29.2	<0.005	<0.005	
HEPTACHLOR (ug/kg)	<0.707	<0.729	<0.005	<0.005	
HEPTACHLOR EPOXIDE (ug/kg)	<0.707	<0.729	<0.005	<0.005	

TABLE G-12 SEDIMENT SAMPLES RESULTS OF ANALYSIS					
SAMPLE ANALYSIS	SD-1	SD-2	EQIPBLK	FLDBLK	TRPBLK
METHOXYCHLOR (ug/kg)	<0.707	<0.729	<0.005	<0.005	
TOXAPHENE (ug/kg)	<70.7	<72.9	<0.5	<0.5	
PCB 1016 (ug/kg)	<14.1	<14.6	<0.1	<0.1	
PCB 1221 (ug/kg)	<140	<150	<0.1	<0.1	
PCB 1232 (ug/kg)	<140	<150	<0.1	<0.1	
PCB-1242 (ug/kg)	<140	<150	<0.1	<0.1	
PCB-1248 (ug/kg)	<140	<150	<0.1	<0.1	
PCB-1254 (ug/kg)	<140	<150	<0.1	<0.1	
PCB-1260 (ug/kg)	<140	<150	<0.1	<0.1	
TPH, AS GAS (mg/kg)	<8.48	<8.75	<0.41	<0.41	
TPH, AS DIESEL (mg/kg)	299	58.3	<0.41	<0.41	
ACETONE (ug/kg)	<11	<11	<10	<10	<10
BENZENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
BROMODICHLOROMETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
BROMOFORM (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
BROMOMETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
CARBON DISULFIDE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
CARBON TETRACHLORIDE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
CHLOROBENZENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
CHLOROETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
CHLOROFORM (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
CHLOROMETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
DIBROMOCHLOROMETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,1-DICHLOROETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,2-DICHLOROETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,1-DICHLOROETHYLENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,2-DICHLOROETHYLENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,2-DICHLOROETHENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,2-DICHLOROPROPANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
CIS-1,3-DICHLOROPROPENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
TRANS-1,3-DICHLOROPROPENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
ETHYLBENZENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
2-HEXANONE (ug/kg)	<11	<11	<10	<10	<10
METHYLENE CHLORIDE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
METHYL ETHYL KETONE (ug/kg)	<11	<11	<10	<10	<10
METHYL ISOBUTYL KETONE (ug/kg)	<11	<11	<10	<10	<10
STYRENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,1,2,2-TETRACHLOROETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
TETRACHLOROETHENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
TOLUENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,1,1-TRICHLOROETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
1,1,2-TRICHLOROETHANE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
TRICHLOROETHENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
VINYL CHLORIDE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
VINYL ACETATE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0
XYLENE (ug/kg)	<5.3	<5.5	<5.0	<5.0	<5.0

**Appendix H**  
**Results of Sieve Analyses**

Boul ders	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes

# U.S. STANDARD SIEVE SIZES



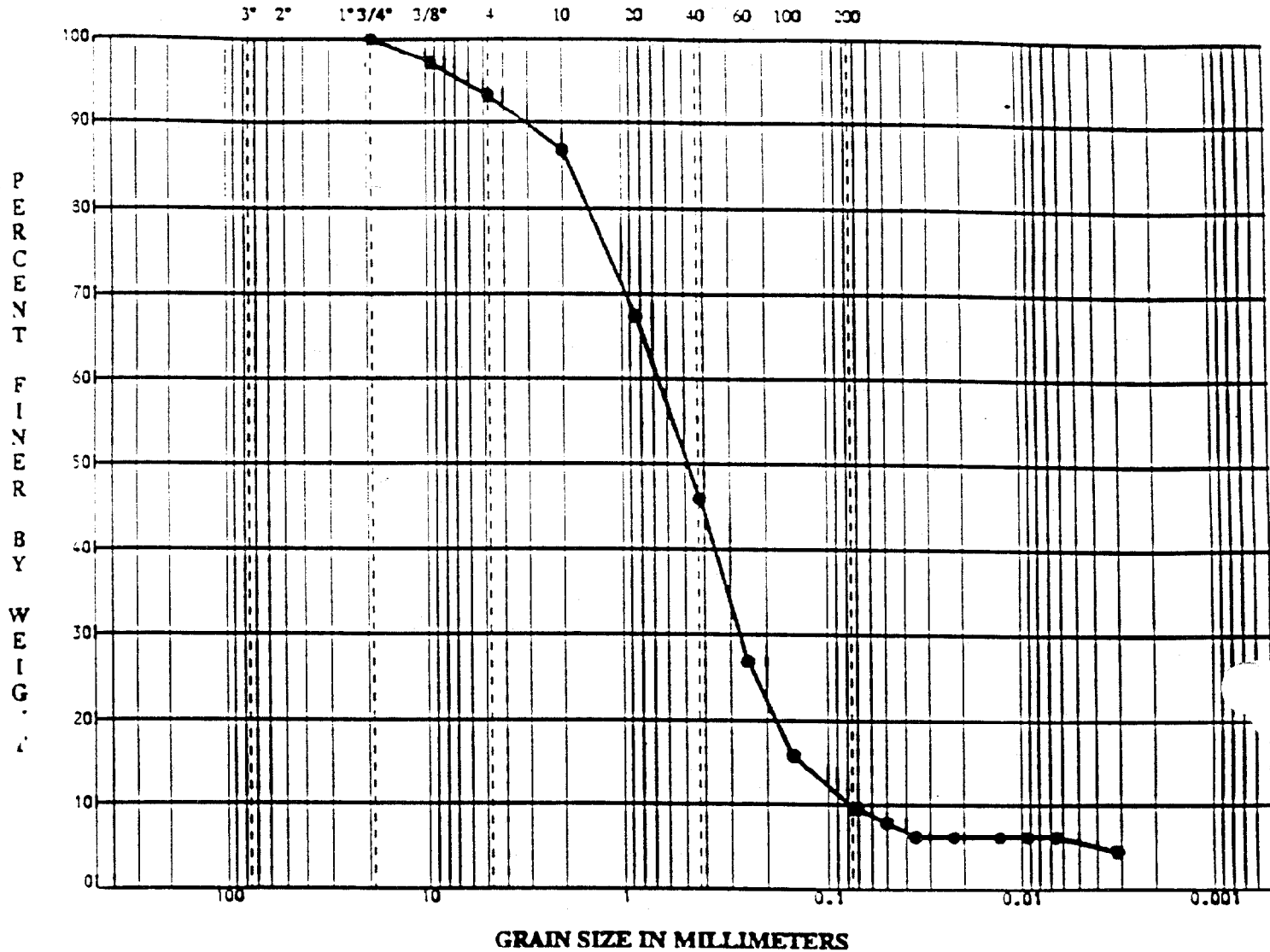
DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
18.0					

SIEVE SIZE	PERCENT PASSING
#4	100.0
#10	99.5
#20	92.9
#40	79.2
#60	61.4
#100	26.9
#200	18.0

GRAIN SIZE DISTRIBUTION	
FIGURE ID	
BORING NUMBER	DW-1
PROJECT NUMBER	W1-
PROJECT	Environmental Science & Engineering, Inc.
LAW ENGINEERING	

Boulder Coarsest	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes

### U.S. STANDARD SIEVE SIZES

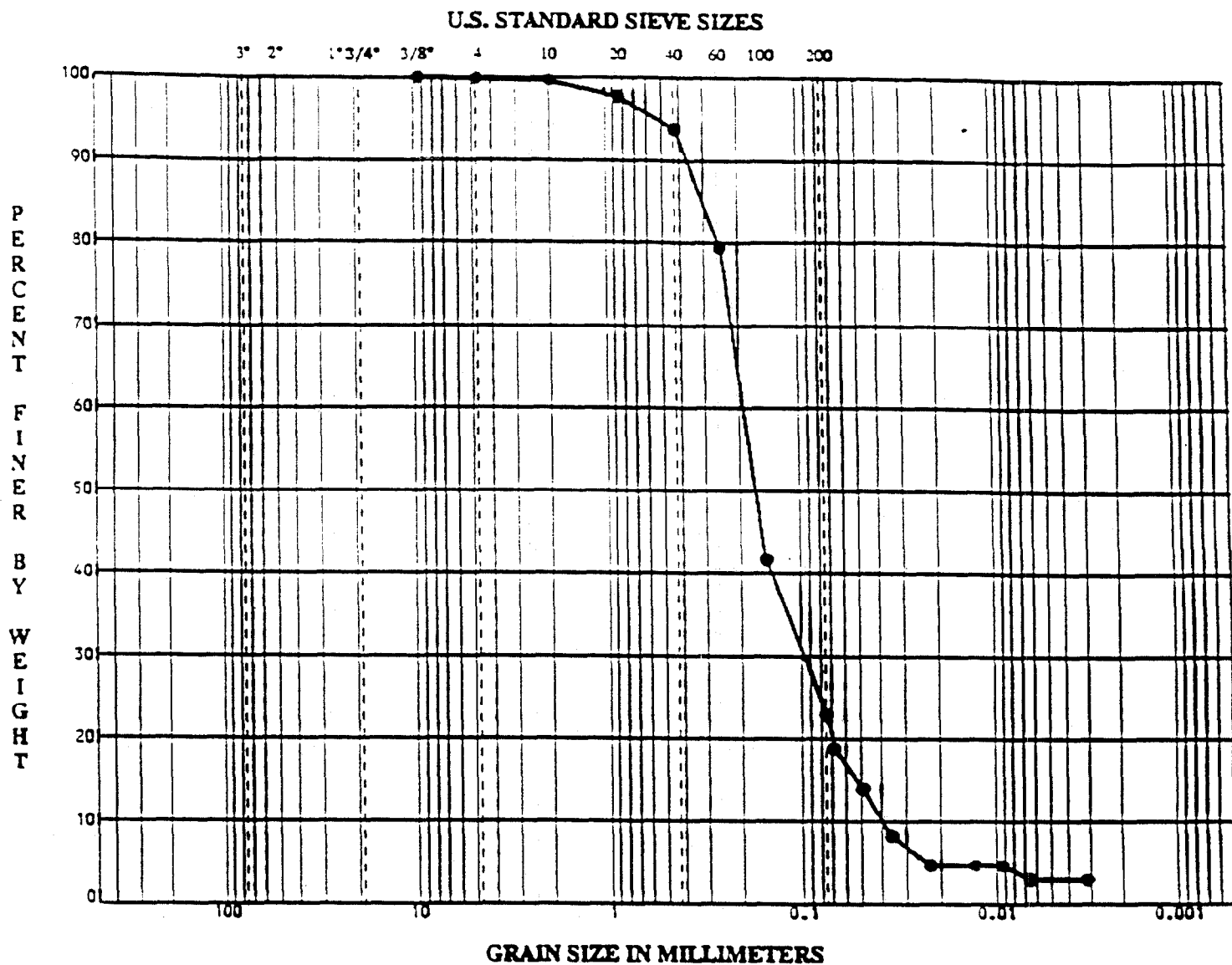


DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
8.0					

SIEVE SIZE	PERCENT PASSING
3/4 in.	100.0
3/8 in.	97.0
#4	93.0
#10	86.7
#20	67.4
#40	45.9
#60	26.8
#100	15.9
#200	9.6

GRAIN SIZE DISTRIBUTION	
FIGURE ID	
BORING NUMBER	DW-1
PROJECT NUMBER	W1-
PROJECT	Environmental Science & Engineering, Inc.
LAW ENGINEERING	

Boul derst	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes



	DEPTH	NAT WC	LL	PL	PI	DESCR'PTION
●	13.0					

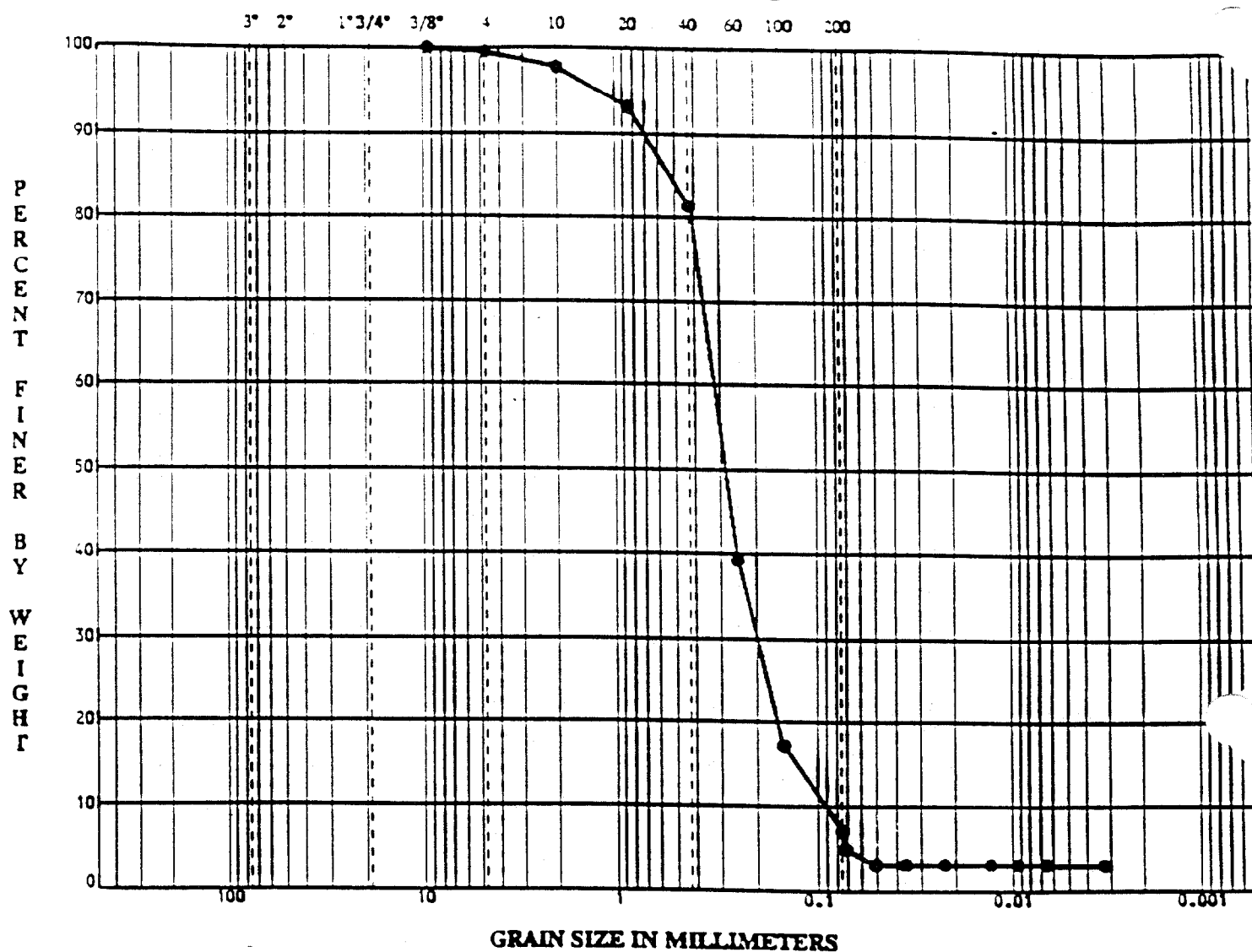
SIEVE SIZE	PERCENT PASSING
3/8 in.	100.0
#4	99.8
#10	99.6
#20	97.6
#40	93.6
#60	79.4
#100	41.6
#200	22.9

GRAIN SIZE DISTRIBUTION	
<b>FIGURE ID</b>	
<b>BORING NUMBER</b>	DW-1
<b>PROJECT NUMBER</b>	W1-
<b>PROJECT</b>	Environmental Science & Engineering, Inc.
<b>LAURENCE ENGINEERING</b>	



Boul densi	COBBLES	GRAVEL		SAND			FINES	
		Coarse	Fine	Coarse	Medium	Fine	Silt Sizes	Clay Sizes

# U.S. STANDARD SIEVE SIZES



DEPTH	NAT WC	LL	PL	PI	DESCRIPTION
22.0					

SIEVE SIZE	PERCENT PASSING
3/8 in.	100.0
#4	99.5
#10	97.7
#20	93.1
#40	81.3
#60	39.3
#100	17.2
#200	7.1

GRAIN SIZE DISTRIBUTION	
FIGURE ID	
BORING NUMBER	DW-1
PROJECT NUMBER	W1-
PROJECT	Environmental Science & Engineering, Inc.
LAW ENGINEERING	

## **Appendix I**

### **Groundwater (MODFLOW) Output File**

	2.17	2.17																		
0 32	.00	.15	.34	.53	.66	.77	.86	.95	1.04	1.13	1.21	1.29	1.37	1.44	1.52					
	1.59	1.66	1.72	1.78	1.84	1.90	1.95	1.99	2.03	2.06	2.09	2.12	2.14	2.15	2.16					
0 33	.00	.16	.36	.54	.67	.77	.87	.96	1.05	1.14	1.22	1.30	1.37	1.45	1.52					
	1.59	1.66	1.72	1.78	1.84	1.89	1.94	1.98	2.02	2.06	2.09	2.11	2.13	2.15	2.16					
0 34	.00	.19	.40	.55	.68	.78	.88	.97	1.06	1.14	1.22	1.30	1.38	1.45	1.53					
	1.60	1.66	1.72	1.78	1.84	1.89	1.94	1.98	2.02	2.05	2.08	2.10	2.12	2.14	2.15					
0 35	.00	.20	.41	.56	.68	.79	.88	.97	1.06	1.15	1.23	1.31	1.38	1.46	1.53					
	1.60	1.66	1.72	1.78	1.84	1.89	1.93	1.98	2.01	2.05	2.07	2.10	2.12	2.13	2.15					
0 36	.00	.21	.42	.57	.69	.79	.89	.98	1.07	1.15	1.23	1.31	1.39	1.46	1.53					
	1.60	1.66	1.72	1.78	1.83	1.88	1.93	1.97	2.01	2.04	2.07	2.09	2.11	2.13	2.14					
0 37	.00	.21	.42	.57	.69	.79	.89	.98	1.07	1.16	1.24	1.32	1.39	1.46	1.53					
	1.60	1.66	1.72	1.78	1.83	1.88	1.93	1.97	2.00	2.04	2.07	2.09	2.11	2.13	2.14					
0 38	.00	.21	.43	.57	.69	.80	.89	.99	1.07	1.16	1.24	1.32	1.39	1.47	1.54					
	1.60	1.66	1.72	1.78	1.83	1.88	1.92	1.97	2.00	2.03	2.06	2.09	2.11	2.12	2.14					
0 39	.00	.21	.43	.58	.70	.80	.90	.99	1.08	1.16	1.24	1.32	1.40	1.47	1.54					
	1.60	1.67	1.72	1.78	1.83	1.88	1.92	1.96	2.00	2.03	2.06	2.08	2.10	2.12	2.13					
0 40	.00	.21	.43	.58	.70	.80	.90	.99	1.08	1.16	1.24	1.32	1.40	1.47	1.54					
	1.60	1.67	1.72	1.78	1.83	1.88	1.92	1.96	2.00	2.03	2.06	2.08	2.10	2.12	2.13					
0 41	.00	.21	.43	.58	.70	.80	.90	.99	1.08	1.16	1.25	1.32	1.40	1.47	1.54					
	1.60	1.67	1.72	1.78	1.83	1.88	1.92	1.96	2.00	2.03	2.06	2.08	2.10	2.12	2.13					
0 42	.00	.21	.43	.58	.70	.80	.90	.99	1.08	1.17	1.25	1.32	1.40	1.47	1.54					
	1.60	1.67	1.72	1.78	1.83	1.88	1.92	1.96	2.00	2.03	2.06	2.08	2.10	2.12	2.13					
0 43	.00	.21	.43	.58	.70	.80	.90	.99	1.08	1.17	1.25	1.33	1.40	1.47	1.54					
	1.60	1.67	1.72	1.78	1.83	1.88	1.92	1.96	2.00	2.03	2.06	2.08	2.10	2.12	2.13					

0 HEAD WILL BE SAVED ON UNIT 50 AT END OF TIME STEP 1, STRESS PERIOD 1

0

#### VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP 1 IN STRESS PERIOD 1

0	CUMULATIVE VOLUMES	L**3	RATES FOR THIS TIME STEP	L**3/T
	IN:		IN:	
	STORAGE = .00000		STORAGE = .00000	
	CONSTANT HEAD = .00000		CONSTANT HEAD = .00000	
	RECHARGE = .31357E+07		RECHARGE = .85910	
0	TOTAL IN = .31357E+07		TOTAL IN = .85910	
0	OUT:		OUT:	
	STORAGE = .00000		STORAGE = .00000	
	CONSTANT HEAD = .31440E+07		CONSTANT HEAD = .86136	
	RECHARGE = .00000		RECHARGE = .00000	
0	TOTAL OUT = .31440E+07		TOTAL OUT = .86136	
0	IN - OUT = -.82553		IN - OUT = -.22617	
0	PERCENT DISCREPANCY = -.26		PERCENT DISCREPANCY = -.26	

0

#### TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	.315360E+08	525600.	8760.00	365.000	.999316
STRESS PERIOD TIME	.315360E+08	525600.	8760.00	365.000	.999316
TOTAL SIMULATION TIME	.315360E+08	525600.	8760.00	365.000	.999316

1

0 23	.00	.03	.07	.00	.64	.69	.76	.84	.91	.99	1.07	1.14	1.21	1.29	1.36
	1.43	1.50	1.57	1.64	1.70	1.77	1.83	1.91	1.96	2.00	2.02	2.04	2.04	2.03	2.02
	1.98	1.97													
0 24	.00	.03	.07	.00	.66	.71	.78	.86	.94	1.01	1.09	1.17	1.24	1.32	1.39
	1.47	1.54	1.61	1.68	1.75	1.81	1.87	1.93	1.98	2.02	2.04	2.06	2.07	2.07	2.06
	2.04	2.03													
0 25	.00	.03	.07	.00	.68	.73	.80	.88	.96	1.04	1.11	1.19	1.27	1.34	1.42
	1.50	1.57	1.64	1.71	1.78	1.85	1.91	1.96	2.00	2.04	2.07	2.09	2.10	2.10	2.09
	2.08	2.08													
0 26	.00	.04	.08	.00	.69	.74	.82	.89	.98	1.06	1.14	1.21	1.29	1.37	1.45
	1.52	1.60	1.67	1.74	1.81	1.87	1.93	1.98	2.03	2.06	2.09	2.11	2.12	2.13	2.13
	2.12	2.11													
0 27	.00	.04	.08	.00	.70	.76	.83	.91	.99	1.07	1.15	1.23	1.31	1.39	1.47
	1.54	1.62	1.69	1.76	1.83	1.90	1.95	2.00	2.04	2.08	2.11	2.13	2.14	2.15	2.15
	2.15	2.14													
0 28	.00	.04	.09	.00	.71	.77	.84	.92	1.01	1.09	1.17	1.25	1.33	1.41	1.48
	1.56	1.64	1.71	1.78	1.85	1.91	1.97	2.01	2.06	2.09	2.12	2.14	2.16	2.17	2.17
	2.17	2.16													
0 29	.00	.04	.00	.64	.70	.77	.85	.94	1.02	1.10	1.19	1.27	1.34	1.42	1.50
	1.58	1.65	1.72	1.79	1.86	1.92	1.97	2.02	2.06	2.10	2.13	2.15	2.16	2.18	2.18
	2.18	2.18													
0 30	.00	.04	.00	.65	.71	.78	.86	.95	1.03	1.12	1.20	1.28	1.36	1.43	1.51
	1.59	1.66	1.73	1.80	1.86	1.92	1.97	2.02	2.06	2.10	2.13	2.15	2.17	2.18	2.18
	2.18	2.18													
0 31	.00	.05	.00	.66	.72	.79	.87	.96	1.04	1.13	1.21	1.29	1.37	1.44	1.52
	1.60	1.67	1.74	1.80	1.86	1.92	1.97	2.01	2.05	2.09	2.12	2.14	2.16	2.17	2.18
	2.18	2.19													
0 32	.00	.05	.00	.67	.72	.80	.88	.97	1.05	1.14	1.22	1.30	1.38	1.45	1.53
	1.60	1.67	1.74	1.80	1.86	1.91	1.96	2.01	2.04	2.08	2.11	2.13	2.15	2.17	2.18
	2.18	2.18													
0 33	.00	.05	.00	.67	.72	.80	.89	.98	1.06	1.14	1.23	1.31	1.38	1.46	1.53
	1.60	1.67	1.74	1.80	1.85	1.90	1.95	2.00	2.03	2.07	2.10	2.12	2.14	2.16	2.17
	2.17	2.18													
0 34	.00	.00	.58	.65	.72	.81	.89	.98	1.07	1.15	1.23	1.31	1.39	1.46	1.54
	1.61	1.67	1.73	1.79	1.85	1.90	1.95	1.99	2.03	2.06	2.09	2.11	2.13	2.15	2.16
	2.17	2.17													
0 35	.00	.00	.58	.64	.72	.81	.90	.99	1.07	1.16	1.24	1.32	1.39	1.47	1.54
	1.61	1.67	1.73	1.79	1.85	1.90	1.94	1.98	2.02	2.06	2.08	2.11	2.13	2.14	2.16
	2.16	2.17													
0 36	.00	.00	.59	.65	.73	.81	.90	.99	1.08	1.16	1.24	1.32	1.40	1.47	1.54
	1.61	1.67	1.73	1.79	1.84	1.89	1.94	1.98	2.02	2.05	2.08	2.10	2.12	2.14	2.15
	2.16	2.16													
0 37	.00	.00	.59	.65	.73	.82	.91	.99	1.08	1.17	1.25	1.33	1.40	1.47	1.54
	1.61	1.67	1.73	1.79	1.84	1.89	1.94	1.98	2.01	2.05	2.08	2.10	2.12	2.14	2.15
	2.16	2.16													
0 38	.00	.00	.59	.65	.73	.82	.91	1.00	1.08	1.17	1.25	1.33	1.40	1.48	1.55
	1.61	1.67	1.73	1.79	1.84	1.89	1.93	1.97	2.01	2.04	2.07	2.10	2.12	2.13	2.14
	2.15	2.16													
0 39	.00	.00	.59	.65	.73	.82	.91	1.00	1.09	1.17	1.25	1.33	1.41	1.48	1.55
	1.61	1.67	1.73	1.79	1.84	1.89	1.93	1.97	2.01	2.04	2.07	2.09	2.11	2.13	2.14
	2.15	2.15													
0 40	.00	.00	.60	.65	.73	.82	.91	1.00	1.09	1.17	1.25	1.33	1.41	1.48	1.55
	1.61	1.67	1.73	1.79	1.84	1.89	1.93	1.97	2.01	2.04	2.07	2.09	2.11	2.13	2.14
	2.15	2.15													
0 41	.00	.00	.60	.65	.74	.82	.91	1.00	1.09	1.17	1.26	1.33	1.41	1.48	1.55
	1.61	1.67	1.73	1.79	1.84	1.89	1.93	1.97	2.01	2.04	2.07	2.09	2.11	2.13	2.14
	2.15	2.15													
0 42	.00	.00	.60	.66	.74	.83	.92	1.00	1.09	1.18	1.26	1.33	1.41	1.48	1.55
	1.61	1.67	1.73	1.79	1.84	1.89	1.93	1.97	2.00	2.04	2.06	2.09	2.11	2.12	2.14
	2.14	2.15													
0 43	.00	.00	.60	.66	.74	.83	.92	1.01	1.09	1.18	1.26	1.33	1.41	1.48	1.55
	1.61	1.67	1.73	1.79	1.84	1.89	1.93	1.97	2.00	2.04	2.06	2.09	2.11	2.12	2.14
	2.14	2.15													

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	31	32													
0 1	.00	.00	.00	.00	.00	.10	.21	.32	.39	.45	.49	.52	.54	.56	.56
	.56	.56	.54	.52	.49	.45	.41	.36	.31	.26	.21	.15	.10	.05	.00
	.00	.00													
0 2	.00	.00	.00	.00	.00	.10	.21	.32	.40	.45	.49	.52	.54	.56	.57
	.57	.56	.54	.52	.49	.45	.41	.36	.31	.25	.20	.15	.10	.05	.00
	.00	.00													
0 3	.00	.00	.00	.00	.00	.10	.21	.33	.40	.46	.50	.53	.55	.57	.58
	.58	.57	.55	.53	.50	.46	.41	.36	.30	.25	.19	.14	.09	.05	.00
	.00	.00													
0 4	.00	.00	.00	.00	.00	.10	.22	.33	.41	.46	.51	.54	.56	.58	.59
	.59	.58	.56	.54	.51	.47	.42	.36	.30	.24	.18	.13	.08	.04	.00

0.5	.00 .61 .00	.00 .60 .00	.00 .58 .00	.00 .56 .00	.00 .52 .00	.11 .48 .00	.23 .42 .00	.35 .36 .00	.42 .29 .00	.48 .22 .00	.52 .15 .00	.55 .10 .00	.58 .06 .00	.60 .03 .00	.60
0.6	.00 .63 .00	.00 .62 .00	.00 .61 .00	.00 .58 .00	.00 .54 .00	.12 .50 .00	.24 .44 .00	.36 .36 .00	.44 .28 .00	.49 .19 .00	.54 .10 .00	.57 .06 .00	.62 .04 .00	.62 .02 .00	.63
0.7	.00 .66 .00	.00 .65 .00	.00 .64 .00	.00 .61 .00	.00 .57 .00	.13 .52 .00	.27 .46 .00	.38 .38 .00	.46 .28 .00	.51 .16 .00	.56 .00 .00	.59 .00 .00	.62 .00 .00	.64 .00 .00	.65
0.8	.00 .69 .00	.00 .69 .00	.00 .67 .00	.00 .65 .00	.07 .61 .00	.18 .56 .00	.31 .49 .00	.41 .40 .00	.48 .29 .00	.53 .16 .00	.58 .00 .00	.62 .00 .00	.65 .00 .00	.67 .00 .00	.68
0.9	.00 .73 .00	.00 .73 .00	.00 .72 .00	.00 .69 .00	.09 .66 .00	.21 .61 .00	.34 .54 .00	.43 .45 .00	.50 .33 .00	.56 .18 .00	.60 .00 .00	.64 .00 .00	.68 .00 .00	.70 .00 .00	.72
0.10	.00 .77 .00	.00 .77 .00	.00 .77 .00	.00 .75 .00	.10 .72 .00	.23 .67 .00	.37 .61 .00	.46 .52 .00	.53 .40 .00	.58 .24 .00	.63 .00 .00	.67 .00 .00	.71 .00 .00	.74 .00 .00	.76
0.11	.00 .82 .00	.00 .82 .00	.00 .82 .00	.00 .81 .00	.11 .79 .00	.25 .75 .00	.39 .69 .00	.48 .61 .00	.55 .50 .00	.61 .36 .00	.66 .19 .00	.71 .00 .00	.74 .00 .00	.77 .00 .00	.80
0.12	.00 .87 .00	.00 .88 .00	.00 .89 .00	.00 .88 .00	.12 .86 .00	.27 .83 .00	.41 .79 .00	.51 .72 .00	.58 .63 .00	.64 .52 .00	.69 .38 .00	.74 .21 .00	.78 .00 .00	.82 .00 .00	.84
0.13	.00 .92 .00	.00 .94 .00	.00 .95 .00	.00 .95 .00	.14 .95 .00	.29 .93 .00	.44 .90 .00	.53 .85 .00	.61 .78 .00	.67 .69 .00	.73 .58 .00	.78 .46 .00	.82 .32 .00	.86 .20 .00	.89
0.14	.00 .97 .34	.00 1.00 .32	.00 1.02 .00	.00 1.03 .00	.16 1.03 .00	.33 1.03 .00	.47 1.01 .00	.56 .99 .00	.64 .94 .00	.70 .88 .00	.76 .80 .00	.81 .70 .00	.86 .60 .00	.90 .49 .00	.94
0.15	.00 1.03 .65	.00 1.06 .62	.00 1.09 .00	.08 1.11 .00	.22 1.12 .00	.39 1.13 .00	.50 1.13 .00	.60 1.12 .00	.67 1.10 .00	.74 1.06 .00	.80 1.00 .00	.85 .93 .00	.90 .85 .00	.95 .77 .00	.99
0.16	.00 1.09 .91	.00 1.12 .89	.00 1.16 .00	.12 1.19 .00	.27 1.21 .00	.43 1.23 .00	.54 1.25 .00	.63 1.25 .00	.70 1.25 .00	.77 1.22 .00	.83 1.18 .00	.89 1.13 .00	.94 1.08 .00	1.00 1.02 .00	1.04
0.17	.00 1.14 .15	.00 1.19 .13	.00 1.23 .00	.14 1.26 .00	.30 1.30 .00	.46 1.33 .00	.57 1.35 .00	.66 1.37 .00	.73 1.38 .00	.80 1.37 .00	.87 1.35 .00	.93 1.32 .00	.99 1.28 .00	1.04 1.23 .00	1.09
0.18	.00 1.19 .13	.00 1.24 .13	.00 1.29 .00	.17 1.33 .00	.34 1.38 .00	.49 1.41 .00	.60 1.45 .00	.69 1.48 .00	.76 1.50 .00	.83 1.51 .00	.90 1.50 .00	.97 1.48 .00	1.03 1.45 .00	1.09 1.42 .00	1.14
0.19	.00 1.25 .15	.00 1.30 .15	.08 1.35 .00	.23 1.40 .00	.40 1.45 .00	.53 1.50 .00	.63 1.54 .00	.72 1.58 .00	.79 1.61 .00	.87 1.63 .00	.94 1.63 .00	1.00 1.62 .00	1.07 1.60 .00	1.13 1.57 .00	1.19
0.20	.00 1.29 .16	.00 1.35 .16	.11 1.41 .00	.27 1.46 .00	.44 1.52 .00	.56 1.57 .00	.66 1.62 .00	.74 1.67 .00	.82 1.71 .00	.90 1.73 .00	.97 1.74 .00	1.04 1.74 .00	1.10 1.73 .00	1.17 1.71 .00	1.23
0.21	.00 1.34 .17	.00 1.40 .17	.13 1.46 .00	.29 1.52 .00	.46 1.58 .00	.58 1.64 .00	.68 1.69 .00	.77 1.74 .00	.85 1.79 .00	.93 1.81 .00	1.00 1.83 .00	1.07 1.84 .0			



0

OUTPUT FLAGS FOR ALL LAYERS ARE THE SAME:

PRINTOUT PRINTOUT SAVE SAVE

1 HEAD IN LAYER 1 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	31	32													
0 1	.00	.00	.00	.00	.02	.05	.00	.41	.44	.47	.50	.53	.55	.57	.57
	.57	.56	.55	.53	.50	.46	.42	.37	.32	.27	.21	.16	.11	.06	.00
	.00	.00													
0 2	.00	.00	.00	.00	.02	.05	.00	.41	.44	.47	.51	.53	.55	.57	.58
	.58	.57	.55	.53	.50	.46	.42	.37	.32	.26	.21	.16	.11	.06	.00
	.00	.00													
0 3	.00	.00	.00	.00	.02	.05	.00	.42	.45	.48	.51	.54	.56	.58	.59
	.59	.58	.56	.54	.51	.47	.42	.37	.31	.26	.20	.15	.10	.05	.00
	.00	.00													
0 4	.00	.00	.00	.00	.03	.05	.00	.43	.45	.49	.52	.55	.57	.59	.60
	.60	.59	.57	.55	.52	.47	.42	.37	.31	.24	.18	.13	.09	.05	.00
	.00	.00													
0 5	.00	.00	.00	.00	.03	.05	.00	.44	.47	.50	.53	.56	.59	.60	.61
	.62	.61	.59	.57	.53	.49	.43	.37	.30	.23	.16	.11	.07	.04	.01
	.00	.00													
0 6	.00	.00	.00	.00	.03	.06	.00	.45	.48	.52	.55	.58	.61	.62	.64
	.64	.63	.62	.59	.55	.51	.45	.37	.29	.20	.11	.07	.04	.02	.01
	.00	.00													
0 7	.00	.00	.00	.00	.03	.06	.00	.46	.50	.53	.57	.60	.63	.65	.66
	.67	.66	.64	.62	.58	.53	.47	.39	.29	.16	.00	.00	.00	.00	.00
	.00	.00													
0 8	.00	.00	.00	.01	.04	.00	.44	.47	.51	.55	.59	.63	.66	.68	.69
	.70	.70	.68	.66	.62	.57	.50	.41	.30	.17	.00	.00	.00	.00	.00
	.00	.00													
0 9	.00	.00	.00	.02	.04	.00	.46	.49	.53	.58	.62	.65	.69	.71	.73
	.74	.74	.73	.71	.67	.62	.55	.46	.34	.19	.00	.00	.00	.00	.00
	.00	.00													
0 10	.00	.00	.00	.02	.05	.00	.48	.51	.56	.60	.64	.68	.72	.75	.77
	.78	.79	.78	.76	.73	.69	.62	.53	.41	.25	.00	.00	.00	.00	.00
	.00	.00													
0 11	.00	.00	.00	.03	.06	.00	.50	.53	.58	.63	.67	.72	.75	.78	.81
	.83	.84	.84	.83	.80	.76	.71	.63	.52	.38	.20	.00	.00	.00	.00
	.00	.00													
0 12	.00	.00	.00	.03	.06	.00	.52	.56	.61	.66	.71	.75	.79	.83	.86
	.88	.90	.90	.90	.88	.85	.81	.74	.66	.54	.40	.22	.00	.00	.00
	.00	.00													
0 13	.00	.00	.00	.03	.07	.00	.55								







```

1      U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0Q Drum Storage Area - Norfolk Naval Base, Norfolk, Virginia
  2 LAYERS      43 ROWS      32 COLUMNS
  1 STRESS PERIOD(S) IN SIMULATION
MODEL TIME UNIT IS DAYS
0/0 UNITS:
ELEMENT OF UNIT: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
  IO UNIT: 10 0 0 0 0 0 0 20 30 0 0 40 0 0 0 0 0 0 0 0 0 0 0 0
0BAS1 - BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 1
ARRAYS RHS AND BUFF WILL SHARE MEMORY.
START HEAD WILL NOT BE SAVED - DRAWDOWN CANNOT BE CALCULATED
23475 ELEMENTS IN X ARRAY ARE USED BY BAS
23475 ELEMENTS OF X ARRAY USED OUT OF 60000
0BCF1 - BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 10
STEADY-STATE SIMULATION
  LAYER  AQUIFER TYPE
  -----
    1      1
    2      0
  7754 ELEMENTS IN X ARRAY ARE USED BY BCF
  26229 ELEMENTS OF X ARRAY USED OUT OF 60000
0RCH1 - RECHARGE PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 20
OPTION 1 - RECHARGE TO TOP LAYER
  1376 ELEMENTS OF X ARRAY USED FOR RECHARGE
  27605 ELEMENTS OF X ARRAY USED OUT OF 60000
0SIP1 - STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM
MAXIMUM OF 50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
  11213 ELEMENTS IN X ARRAY ARE USED BY SIP
  38818 ELEMENTS OF X ARRAY USED OUT OF 60000
1Q Drum Storage Area - Norfolk Naval Base, Norfolk, Virginia
0

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BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (32I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
	31	32																													
0 1	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	
	-1	-1																													
0 2	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
	-1	-1																													
0 3	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
	-1	-1																													
0 4	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
	-1	-1																													
0 5	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	-1	-1																													
0 6	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	-1	-1																													
0 7	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1
	-1	-1																													
0 8	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
	-1	-1																													
0 9	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	-1
	-1	-1																													
0 10	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1
	-1	-1																													
0 11	-1	-1	-1	-1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1
	-1	-1																													
0 12	-1	-1	-1	-1	1	1	0	1</																							

```

      1 1
022 -1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
023 -1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
024 -1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
025 -1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
026 -1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
027 -1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
028 -1 1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
029 -1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
030 -1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
031 -1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
032 -1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
033 -1 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
034 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
035 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
036 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
037 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
038 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
039 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
040 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
041 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
042 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
043 -1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      1 1
0

```

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (3213)

```

      1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
      31 32
0 1 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 2 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 3 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 4 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 5 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 6 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 7 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 8 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
0 9 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
010 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
011 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
012 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
013 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
      -1 -1
014 -1 -1 -1 -1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1

```

## **Appendix J**

### **Soil and Groundwater Exposure Concentration Summary**

## Definition of Terms for Tables J-1 and J-2

---

PARAMETER	=	Analytical parameter name
BEST EST OF MEAN	=	Best estimate of the arithmetic mean using normal or lognormal distribution theory
UPPER 95% CONF LIMIT	=	Upper 95 percent confidence limit ( $UCL_{95}$ ) determined for either the lognormally or normally distributed data set
DATASET CHOSEN	=	Data set [lognormal or actual (normal)] chosen to calculate the $UCL_{95}$
N	=	Number of records
CV ACTUAL	=	Coefficient of variation (standard deviation divided by the best estimate of the mean)
PROB < W ACTUAL	=	Shapiro-Wilk W statistic (with Royston modification) for determining if the data are normally distributed. Values closer to unity indicate that the data are normally distributed.
PROB < W LN	=	Shapiro-Wilk W-statistic (with Royston modification) for determining if the data are lognormally distributed. Values closer to unity indicate that the data are lognormally distributed.
MAX HIT	=	Maximum detected concentration
EXPOSURE CONC	=	The exposure concentration is either the $UCL_{95}$ or the maximum detected concentration. If the $UCL_{95}$ exceeds the maximum detected concentration, then the maximum detected concentration is used as the exposure concentration. Otherwise, the $UCL_{95}$ is used as the exposure concentration.
DEL ND*	=	A "1" in this column is represented by "Delete ND > Max Hit". This means that when the $UCL_{95}$ exceeds the maximum positively quantified value in the data set, all nondetects have been deleted where the detection limit is greater than the maximum hit. A "2" in this column is represented by "Delete ND > Min ND". This means that all elevated nondetects are deleted (where elevation is defined as when the detection limit is greater than the minimum detection limit).

---

Table J-1. SOIL EXPOSURE CONCENTRATIONS  
(COMBINED RESULTS OF RUNS 1 AND 2 MG/KG)

10:29 Thursday, October 5, 1995

PARAMETER	BEST EST OF MEAN	UPPER 95% CONF LIMIT	DATASET CHOSEN	N	CV ACTUAL	PROB<W ACTUAL	PROB<W LN	MAX HIT	EXPOSURE CONC	DEL NO*	PARAMETER
111TCE	1.00E-03		CASE2ACT	1				1.00E-03	1.00E-03	1	111TCE
11DCE	2.81E-03	3.14E-03	CASE2ACT	57	5.31E-01	0.00E+00	0.00E+00	5.00E-03	3.14E-03		11DCE
124TCB	2.58E-01	5.43E-01	CASE3ACT	12	2.12E+00	1.00E-04	1.00E-04	2.00E+00	5.43E-01		124TCB
12DCE	4.99E-03	6.58E-03	CASE3LN	57	6.68E+00	0.00E+00	0.00E+00	1.50E+00	6.58E-03		12DCE
14DCLB	2.58E-01	5.43E-01	CASE3ACT	12	2.12E+00	1.00E-04	1.00E-04	2.00E+00	5.43E-01		14DCLB
24DMPN	5.14E-01	1.06E+00	CASE3LN	12	1.96E+00	1.00E-04	1.00E-04	4.80E+00	1.06E+00		24DMPN
24DNT	2.42E-01	4.96E-01	CASE3ACT	12	2.03E+00	1.00E-04	1.00E-04	1.80E+00	4.96E-01		24DNT
ACET	4.58E-02	8.11E-02	CASE3LN	57	2.19E+00	0.00E+00	1.00E-04	6.50E-01	8.11E-02		ACET
ACLDAN	4.92E-03	9.53E-03	CASE2ACT	5	9.83E-01	2.63E-01	2.99E-01	1.20E-02	9.53E-03		ACLDAN
AG	9.53E-02	3.12E-01	CASE3LN	12	2.13E+00	1.00E-04	1.00E-04	1.00E+00	3.12E-01		AG
AL	4.68E+03	5.47E+03	CASE2ACT	5	1.78E-01	4.40E-01	4.69E-01	5.55E+03	5.47E+03		AL
ALDRN	1.40E-03		CASE2ACT	1				1.40E-03	1.40E-03	1	ALDRN
ANAPNE	2.58E-01	5.43E-01	CASE3ACT	12	2.12E+00	1.00E-04	1.00E-04	2.00E+00	5.43E-01		ANAPNE
AS	1.25E+01	1.59E+01	CASE2ACT	17	6.37E-01	3.03E-01	1.00E-04	3.20E+01	1.59E+01		AS
B2EHP	7.35E-02	2.41E-01	CASE2ACT	2	5.10E-01	0.00E+00	0.00E+00	1.00E-01	1.00E-01	1	B2EHP
BA	4.45E+01	5.40E+01	CASE2ACT	5	2.26E-01	2.46E-01	3.15E-01	5.66E+01	5.40E+01		BA
BAANTR	1.11E-01	1.33E-01	CASE2ACT	13	4.06E-01	1.00E-04	1.00E-04	2.60E-01	1.33E-01	1	BAANTR
BAPYR	8.50E-02		CASE2ACT	1				8.50E-02	8.50E-02	1	BAPYR
BBFANT	1.30E-01		CASE2ACT	1				1.30E-01	1.30E-01	1	BBFANT
BBHC	2.82E-03	5.71E-03	CASE2ACT	3	6.09E-01	2.23E-01	1.16E-01	4.00E-03	4.00E-03	1	BBHC
BBZP	1.82E-01	2.12E-01	CASE2ACT	21	4.37E-01	1.00E-04	1.00E-04	5.30E-01	2.12E-01		BBZP
BGHIPI	7.80E-02		CASE2ACT	1				7.80E-02	7.80E-02	1	BGHIPI
BKFANT	6.10E-02		CASE2ACT	1				6.10E-02	6.10E-02	1	BKFANT
C6H6	2.00E-03		CASE2ACT	1				2.00E-03	2.00E-03	1	C6H6
CA	9.53E+04	1.30E+05	CASE2ACT	5	3.78E-01	2.24E-01	3.36E-01	1.36E+05	1.30E+05		CA
CD-S*	1.07E+00	1.29E+00	CASE2ACT	12	3.98E-01	2.55E-01	1.89E-01	2.00E+00	1.29E+00		CD-S*
CH2CL2	1.09E-02	1.52E-02	CASE2ACT	22	1.08E+00	1.00E-04	1.00E-04	3.90E-02	1.52E-02		CH2CL2
CHRY	1.13E-01	1.35E-01	CASE2ACT	13	3.91E-01	1.00E-04	1.00E-04	2.60E-01	1.35E-01	1	CHRY
CR	1.32E+01	1.50E+01	CASE2ACT	17	3.24E-01	3.94E-01	3.08E-01	2.00E+01	1.50E+01		CR
CU	7.08E+00	1.01E+01	CASE2ACT	17	1.01E+00	4.90E-03	4.61E-01	2.43E+01	1.01E+01		CU
DBHC	1.10E-03		CASE2ACT	1				1.10E-03	1.10E-03	1	DBHC
DNBP	2.58E-01	5.43E-01	CASE3ACT	12	2.12E+00	1.00E-04	1.00E-04	2.00E+00	5.43E-01		DNBP
ESFSO4	2.67E-03	5.66E-03	CASE3ACT	12	2.17E+00	1.00E-04	1.00E-04	2.10E-02	5.66E-03		ESFSO4
FANT	1.53E-01	2.29E-01	CASE2ACT	14	1.04E+00	1.00E-04	1.00E-04	7.00E-01	2.29E-01	1	FANT
FE	1.68E+04	1.72E+04	CASE2ACT	5	2.62E-02	6.71E-01	6.92E-01	1.74E+04	1.72E+04		FE
GCLDAN	6.14E-03	1.16E-02	CASE2ACT	5	9.40E-01	3.69E-01	1.83E-01	1.40E-02	1.16E-02		GCLDAN
HG	7.75E-02	1.10E-01	CASE2ACT	12	8.03E-01	7.00E-03	4.77E-01	2.40E-01	1.10E-01		HG
ICDPYR	8.30E-02		CASE2ACT	1				8.30E-02	8.30E-02	1	ICDPYR
K	2.02E+03	2.94E+03	CASE1LN	5	2.98E-01	9.67E-01	9.13E-01	2.80E+03	2.80E+03	1	K
LIN	1.10E-03		CASE2ACT	1				1.10E-03	1.10E-03	1	LIN
MEC6H5	3.34E-03	3.79E-03	CASE3LN	63	3.49E+00	0.00E+00	0.00E+00	1.40E-01	3.79E-03		MEC6H5
MG	3.78E+03	4.70E+03	CASE2ACT	5	2.58E-01	6.80E-03	1.56E-02	5.50E+03	4.70E+03		MG
MN-S*	2.86E+02	3.31E+02	CASE2ACT	5	1.63E-01	2.28E-01	3.35E-01	3.62E+02	3.31E+02		MN-S*
NA	1.14E+03		CASE2ACT	1				1.14E+03	1.14E+03		NA
NI	6.18E+00	8.60E+00	CASE2ACT	17	9.22E-01	3.10E-03	4.39E-01	2.20E+01	8.60E+00		NI
NNONPA	9.25E-01	2.41E+00	CASE3ACT	12	3.09E+00	1.00E-04	1.00E-04	1.00E+01	2.41E+00		NNONPA
PB	2.39E+01	3.41E+01	CASE2ACT	17	1.00E+00	1.00E-04	7.67E-01	1.05E+02	3.41E+01		PB
PHANTR	1.61E-01	2.30E-01	CASE2ACT	14	9.19E-01	1.00E-04	1.00E-04	6.00E-01	2.30E-01	1	PHANTR
PHENOL	1.03E+00	2.50E+00	CASE3LN	17	1.27E+00	1.00E-04	1.00E-04	3.40E+00	2.50E+00		PHENOL
PPDDO	1.17E-02	5.92E-02	CASE3LN	16	2.44E+00	1.00E-04	1.00E-04	1.60E-01	5.92E-02		PPDDO
PPDDE	1.79E-03	2.46E-03	CASE2ACT	16	8.50E-01	1.00E-04	1.00E-04	5.70E-03	2.46E-03		PPDDE
PPDOT	1.09E-03	1.26E-03	CASE2ACT	12	2.91E-01	1.00E-04	1.00E-04	2.10E-03	1.26E-03		PPDOT
PYR	2.26E-01	4.04E-01	CASE3LN	14	1.68E+00	1.00E-04	1.00E-04	1.80E+00	4.04E-01	1	PYR
SB	1.48E+00	2.40E+00	CASE2ACT	5	6.53E-01	2.10E-03	1.19E-02	3.20E+00	2.40E+00		SB
TCLEE	6.05E-03	7.97E-03	CASE3LN	62	2.79E+00	0.00E+00	0.00E+00	1.50E-01	7.97E-03		TCLEE
TL	8.66E+00	1.25E+01	CASE2ACT	12	8.62E-01	2.72E-02	1.00E-01	2.20E+01	1.25E+01		TL
V	3.88E+01	4.79E+01	CASE2ACT	5	2.45E-01	5.48E-01	7.34E-01	5.32E+01	4.79E+01		V
XYLEN	2.00E-03		CASE2ACT	1				2.00E-03	2.00E-03	1	XYLEN
ZN	3.22E+01	4.23E+01	CASE2ACT	17	7.46E-01	8.00E-03	7.22E-02	1.00E+02	4.23E+01		ZN

\* 1 = DELETE NO > MAX HIT  
2 = DELETE NO > MIN NO

Source: ESE.

Table J-2. GROUNDWATER EXPOSURE CONCENTRATIONS  
(COMBINED RESULTS OF RUNS 1 AND 2 MG/L)

15:00 Thursday, October 5, 1995

PARAMETER	BEST EST OF MEAN	UPPER 95% CONF LIMIT	DATASET CHOSEN	N	CV ACTUAL	PROB<W ACTUAL	PROB<W LN	MAX HIT	EXPOSURE CONC	DEL ND*	PARAMETER
111TCE	1.46E+00	1.94E+02	CASE3LN	12	1.29E+00	8.00E-03	3.22E-02	1.10E+00	1.10E+00	1	111TCE
11DCE	8.28E-02	1.30E-01	CASE2ACT	12	1.09E+00	1.01E-02	3.63E-01	1.40E-01	1.30E-01		11DCE
11DCL	8.43E-02	3.76E-01	CASE3LN	27	1.93E+00	1.00E-04	1.00E-03	5.40E-01	3.76E-01		11DCL
12DCE	1.51E-01	6.64E-01	CASE3LN	21	1.43E+00	1.00E-04	1.60E-03	5.00E-01	5.00E-01	1	12DCE
ACET	3.98E-01	6.45E-01	CASE2ACT	12	1.20E+00	8.40E-03	1.59E-02	1.30E+00	6.45E-01		ACET
AG	5.25E-03	6.79E-03	CASE2ACT	11	5.36E-01	2.02E-02	2.00E-01	1.20E-02	6.79E-03		AG
AS	9.10E-03	2.83E-02	CASE3LN	20	2.45E+00	1.00E-04	1.23E-02	1.20E-01	2.83E-02		AS
B2ENP	1.07E-02	5.50E-02	CASE3LN	8	1.62E+00	1.00E-04	6.02E-01	5.40E-02	5.40E-02	1	B2ENP
BA	8.18E-02	1.12E-01	CASE2ACT	7	5.01E-01	5.00E-04	4.90E-03	1.73E-01	1.12E-01		BA
BE	2.84E-03	3.60E-03	CASE2ACT	10	4.63E-01	3.40E-02	2.46E-02	5.00E-03	3.60E-03		BE
BRDCLM	1.34E-01	1.44E+00	CASE3LN	12	1.22E+00	1.40E-03	1.06E-02	1.20E-01	1.20E-01	1	BRDCLM
C2H3CL	1.78E-01	2.88E-01	CASE2ACT	12	1.20E+00	1.60E-03	7.30E-03	3.40E-02	3.40E-02	1	C2H3CL
CA	2.20E+02	3.19E+02	CASE2ACT	9	7.28E-01	9.91E-02	5.70E-01	5.05E+02	3.19E+02		CA
CCL4	8.86E-02	1.43E-01	CASE2ACT	12	1.18E+00	2.30E-03	6.50E-03	1.20E-01	1.20E-01	1	CCL4
CD-A*	3.33E-03	4.76E-03	CASE2ACT	19	1.08E+00	1.00E-04	7.00E-04	1.50E-02	4.76E-03		CD-A*
CH2CL2	8.67E-03	1.46E-02	CASE2ACT	3	4.05E-01	8.43E-01	6.27E-01	9.00E-03	9.00E-03	1	CH2CL2
CHCL3	9.22E-02	1.46E-01	CASE2ACT	12	1.13E+00	4.00E-03	2.44E-02	6.00E-02	6.00E-02	1	CHCL3
CR	2.95E-02	1.03E-01	CASE3LN	11	1.78E+00	1.00E-04	1.50E-01	2.06E-01	1.03E-01		CR
CU	1.15E-02	2.79E-02	CASE3LN	10	1.32E+00	1.00E-04	4.10E-03	5.50E-02	2.79E-02		CU
FE	3.34E+00	1.04E+03	CASE3LN	7	1.67E+00	1.90E-03	8.37E-01	7.79E+00	7.79E+00	1	FE
HG	1.55E-04	2.03E-04	CASE2ACT	11	5.69E-01	6.10E-03	1.20E-03	3.00E-04	2.03E-04		HG
K	1.25E+02	1.62E+02	CASE2ACT	9	4.70E-01	8.20E-02	5.39E-01	2.37E+02	1.62E+02		K
MG	3.95E+02	5.58E+02	CASE2ACT	9	6.68E-01	1.19E-01	4.18E-01	7.96E+02	5.58E+02		MG
MN-A*	8.58E-01	1.38E+00	CASE2ACT	9	9.86E-01	1.90E-03	1.08E-01	2.73E+00	1.38E+00		MN-A*
NA	3.56E+03	4.86E+03	CASE2ACT	9	5.84E-01	1.81E-01	2.49E-01	6.66E+03	4.86E+03		NA
NI	2.24E-02	3.60E-02	CASE2ACT	10	1.05E+00	1.00E-04	3.10E-03	8.70E-02	3.60E-02		NI
PB	1.16E-02	5.14E-02	CASE3LN	20	2.07E+00	1.00E-04	1.75E-02	1.02E-01	5.14E-02		PB
SB	4.44E-02	4.95E-02	CASE2ACT	10	1.99E-01	5.01E-02	2.26E-02	5.20E-02	4.95E-02		SB
SE	7.00E-03	2.82E-02	CASE3LN	11	2.46E+00	1.00E-04	1.10E-03	9.00E-02	2.82E-02		SE
TCLEE	1.21E-02	3.05E-02	CASE3LN	36	2.35E+00	1.00E-04	1.00E-04	1.55E-01	3.05E-02		TCLEE
TL	1.68E-03	2.74E-03	CASE2ACT	9	1.02E+00	1.60E-02	4.16E-02	5.50E-03	2.74E-03		TL
TRCLE	1.18E-01	4.45E-01	CASE3LN	36	2.53E+00	1.00E-04	1.01E-01	1.37E+00	4.45E-01		TRCLE
ZN	6.85E-02	3.45E-01	CASE3LN	16	1.99E+00	1.00E-04	5.16E-02	4.16E-01	3.45E-01		ZN

\* 1 = DELETE NO > MAX HIT  
2 = DELETE NO > MIN NO

Source: ESE.

Medium	Chemname	Source	Sampid	Conc	Units
Groundwater	Acetone	ESE, Oct 1990 (Table G-7)	DW-1	<	.010000 MG/L
			GW-1-1		.110000 MG/L
			GW-1-2		.007000 MG/L
			SW-1-1		1.300000 MG/L
			SW-1-1FD		.150000 MG/L
			SW-1-2		.830000 MG/L
			SW-2-1		.960000 MG/L
			SW-2-2		.920000 MG/L
			SW-4-1		.007000 MG/L
			SW-4-2		.009000 MG/L
			SW-6-1	<	.010000 MG/L
			SW-6-2		.460000 MG/L
	Antimony	ESE, Jan 1991 (Table G-10)	GW-1-2		.033000 MG/L
			GW-3-2		.027000 MG/L
			GW-4-2		.041000 MG/L
			SW-1-2		.052000 MG/L
			SW-3-2		.052000 MG/L
			SW-4-2		.052000 MG/L
	Arsenic	ESE, Oct 1992 (Table G-11)	DW-1		.051200 MG/L
			DW-2		.047700 MG/L
			SW-2		.047800 MG/L
			SW-5		.040400 MG/L
		Baker, May 1995	DW-3		.002100 MG/L
			DW-4	<	.008500 MG/L
			DW-5	<	.001400 MG/L
			DW-6	<	.001400 MG/L
			DW-7	<	.001400 MG/L
			DW-8	<	.001400 MG/L
			SW-10	<	.001400 MG/L
			SW-9	<	.001400 MG/L
		ESE, Jan 1991 (Table G-10)	GW-1-2		.020300 MG/L
			GW-3-2		.014700 MG/L
			GW-4-2		.007500 MG/L
			SW-1-2		.007800 MG/L
			SW-3-2		.003800 MG/L
			SW-4		.120000 MG/L
			SW-4-2		.014800 MG/L
		ESE, Oct 1992 (Table G-11)	DW-1		.001500 MG/L
			DW-2		.001500 MG/L
			SW-2		.010900 MG/L
			SW-5		.001500 MG/L
	Barium	Baker, May 1995	DW-4		.072000 MG/L
			DW-5		.079000 MG/L
			DW-8		.058800 MG/L
			SW-10		.070000 MG/L
			SW-9		.058900 MG/L
					.060700 MG/L
	Beryllium	ESE, Jan 1991 (Table G-10)	SW-4		.173000 MG/L
		ESE, Jan 1991 (Table G-10)	GW-1-2		.005000 MG/L
			GW-3-2		.004000 MG/L
			GW-4-2		.004000 MG/L
			SW-1-2		.003000 MG/L
			SW-3-2		.002000 MG/L
			SW-4-2		.004000 MG/L
		ESE, Oct 1992 (Table G-11)	DW-1		.001600 MG/L
			DW-2		.001600 MG/L
			SW-2		.001600 MG/L
			SW-5		.001600 MG/L
	Bis(2-ethylhexyl) phthalate	Baker, May 1995	DW-3		.008000 MG/L
			DW-5		.004000 MG/L
			DW-6		.008000 MG/L
			DW-7		.007000 MG/L
			DW-8		.001000 MG/L
			SW-10		.002000 MG/L
			SW-9		.003000 MG/L
					.054000 MG/L
	Bromodichloromethane	ESE, Oct 1990 (Table G-7)	DW-1		.004000 MG/L
			GW-1-1	<	.012000 MG/L
			GW-1-2	<	.005000 MG/L



Medium	Chemname	Source	Sampled	Conc	Units	
Groundwater	Bromodichloromethane	ESE, Oct 1990 (Table G-7)	SW-1-1	.120000	MG/L	
			SW-1-1FD	< .025000	MG/L	
			SW-1-2	.120000	MG/L	
			SW-2-1	< .250000	MG/L	
			SW-2-2	< .250000	MG/L	
			SW-4-1	< .005000	MG/L	
			SW-4-2	< .005000	MG/L	
			SW-6-1	< .005000	MG/L	
		SW-6-2	< .250000	MG/L		
		Cadmium (aqueous matrix)	Baker, May 1995	DW-3	< .003900	MG/L
				DW-4	< .003900	MG/L
				DW-5	.007300	MG/L
				DW-6	.005800	MG/L
				DW-7	< .003900	MG/L
				DW-8	< .003900	MG/L
	SW-9			< .003900	MG/L	
	ESE, Jan 1991 (Table G-10)	GW-1-2	.003000	MG/L		
		GW-3-2	.003000	MG/L		
		GW-4-2	.008000	MG/L		
		SW-1-2	.003000	MG/L		
		SW-3-2	.003000	MG/L		
		SW-4	.003000	MG/L		
		SW-4-2	.015000	MG/L		
	ESE, Oct 1992 (Table G-11)	DW-1	.000100	MG/L		
		DW-2	.000100	MG/L		
		SW-2	.000100	MG/L		
		SW-5	.000100	MG/L		
	Calcium	Baker, May 1995	DW-3	183.000000	MG/L	
			DW-4	505.000000	MG/L	
			DW-5	372.000000	MG/L	
			DW-6	388.000000	MG/L	
			DW-7	73.500000	MG/L	
			DW-8	54.900000	MG/L	
			SW-10	140.000000	MG/L	
			SW-9	130.000000	MG/L	
	Carbon tetrachloride	ESE, Oct 1990 (Table G-7)	DW-1	< .005000	MG/L	
GW-1-1			< .012000	MG/L		
GW-1-2			< .005000	MG/L		
SW-1-1			.120000	MG/L		
SW-1-1FD			.072000	MG/L		
SW-1-2			.084000	MG/L		
SW-2-1			< .250000	MG/L		
SW-2-2			< .250000	MG/L		
SW-4-1			< .005000	MG/L		
SW-4-2			< .005000	MG/L		
SW-6-1			< .005000	MG/L		
SW-6-2			< .250000	MG/L		
Chloroform	ESE, Oct 1990 (Table G-7)	DW-1	.060000	MG/L		
		GW-1-1	< .012000	MG/L		
		GW-1-2	< .005000	MG/L		
		SW-1-1	< .120000	MG/L		
		SW-1-1FD	< .025000	MG/L		
		SW-1-2	< .120000	MG/L		
		SW-2-1	< .250000	MG/L		
		SW-2-2	< .250000	MG/L		
		SW-4-1	< .005000	MG/L		
		SW-4-2	< .005000	MG/L		
		SW-6-1	< .005000	MG/L		
		SW-6-2	< .250000	MG/L		
Chromium, total	ESE, Jan 1991 (Table G-10)	GW-1-2	.018000	MG/L		
		GW-3-2	.022000	MG/L		
		GW-4-2	.063000	MG/L		
		SW-1-2	.015000	MG/L		
		SW-3-2	.009000	MG/L		
		SW-4	.004000	MG/L		
		SW-4-2	.206000	MG/L		
	ESE, Oct 1992 (Table G-11)	DW-1	.005300	MG/L		
		DW-2	.005300	MG/L		
		SW-2	.012300	MG/L		
		SW-5	.008800	MG/L		

Medium	Chemname	Source	Sampid	Conc	Units
Groundwater	Copper	ESE, Jan 1991 (Table G-10)	GW-1-2	.011000	MG/L
			GW-3-2	.009000	MG/L
			GW-4-2	.023000	MG/L
			SW-1-2	.004000	MG/L
			SW-3-2	.004000	MG/L
			SW-4-2	.055000	MG/L
		ESE, Oct 1992 (Table G-11)	DW-1	.004200	MG/L
			DW-2	.004200	MG/L
			SW-2	.004200	MG/L
			SW-5	.004200	MG/L
	Dichloroethane, 1,1-	Baker, May 1995	DW-3	.009000	MG/L
			DW-4	< .010000	MG/L
			DW-5	< .010000	MG/L
			DW-6	< .010000	MG/L
			DW-7	< .010000	MG/L
			DW-8	< .010000	MG/L
			SW-10	< .010000	MG/L
			SW-9	< .010000	MG/L
				< .010000	MG/L
		ESE, Jan 1993 (Table G-8)	FD-1	.001000	MG/L
			FD-2	< .001000	MG/L
			SW-10-D	.002800	MG/L
			SW-10-S	.002500	MG/L
			SW-9-D	< .001000	MG/L
			SW-9-S	< .001000	MG/L
		ESE, Oct 1990 (Table G-7)	DW-1	.003000	MG/L
			GW-1-1	.021000	MG/L
			GW-1-2	< .005000	MG/L
			SW-1-1	.290000	MG/L
			SW-1-1FD	.240000	MG/L
			SW-1-2	.210000	MG/L
			SW-2-1	.520000	MG/L
			SW-2-2	.540000	MG/L
			SW-4-1	.013000	MG/L
			SW-4-2	.021000	MG/L
			SW-6-1	.016000	MG/L
			SW-6-2	< .250000	MG/L
	Dichloroethene, 1,1-	ESE, Oct 1990 (Table G-7)	DW-1	< .005000	MG/L
			GW-1-1	< .012000	MG/L
			GW-1-2	< .005000	MG/L
			SW-1-1	< .120000	MG/L
			SW-1-1FD	.033000	MG/L
			SW-1-2	.097000	MG/L
			SW-2-1	.140000	MG/L
			SW-2-2	< .250000	MG/L
			SW-4-1	.028000	MG/L
			SW-4-2	.041000	MG/L
			SW-6-1	.013000	MG/L
			SW-6-2	< .250000	MG/L
	Dichloroethenes, 1,2-, total	Baker, May 1995	DW-3	< .010000	MG/L
			DW-4	< .010000	MG/L
			DW-5	< .010000	MG/L
			DW-6	< .010000	MG/L
			DW-7	.022000	MG/L
			DW-8	.110000	MG/L
			SW-10	< .010000	MG/L
			SW-9	.032000	MG/L
				.047000	MG/L
		ESE, Oct 1990 (Table G-7)	DW-1	< .005000	MG/L
			GW-1-1	.500000	MG/L
			GW-1-2	< .005000	MG/L
			SW-1-1	.230000	MG/L
			SW-1-1FD	.130000	MG/L
			SW-1-2	.150000	MG/L
			SW-2-1	.430000	MG/L
			SW-2-2	.400000	MG/L
			SW-4-1	< .005000	MG/L
			SW-4-2	< .005000	MG/L
			SW-6-1	.050000	MG/L
			SW-6-2	.120000	MG/L
	Iron	Baker, May 1995	DW-3	3.330000	MG/L
			DW-4	7.790000	MG/L
			DW-6	< .031400	MG/L

Medium	Chemname	Source	Sampid	Conc	Units
Groundwater	Iron	Baker, May 1995	DW-8	.105000	MG/L
			SW-10	.458000	MG/L
			SW-9	.234000	MG/L
				.244000	MG/L
	Lead	Baker, May 1995	DW-3	<	.004000 MG/L
			DW-4	<	.000800 MG/L
			DW-5	<	.004000 MG/L
			DW-6	<	.004800 MG/L
			DW-7	<	.000800 MG/L
			DW-8	<	.000800 MG/L
			SW-10	<	.000800 MG/L
			SW-9	<	.000800 MG/L
				<	.000800 MG/L
		ESE, Jan 1991 (Table G-10)	GW-1-2		.017800 MG/L
			GW-3-2		.026900 MG/L
			GW-4-2		.019300 MG/L
			SW-1-2		.004500 MG/L
			SW-3-2		.001800 MG/L
			SW-4		.043000 MG/L
			SW-4-2		.102000 MG/L
		ESE, Oct 1992 (Table G-11)	DW-1		.001500 MG/L
			DW-2		.001500 MG/L
			SW-2		.001500 MG/L
			SW-5		.001500 MG/L
	Magnesium	Baker, May 1995	DW-3		312.000000 MG/L
			DW-4		631.000000 MG/L
			DW-5		756.000000 MG/L
			DW-6		796.000000 MG/L
			DW-7		149.000000 MG/L
			DW-8		79.000000 MG/L
			SW-10		288.000000 MG/L
			SW-9		269.000000 MG/L
					273.000000 MG/L
	Manganese	Baker, May 1995	DW-3		.338000 MG/L
			DW-4		.589000 MG/L
			DW-5		2.730000 MG/L
			DW-6		1.830000 MG/L
			DW-7		.272000 MG/L
			DW-8		.332000 MG/L
			SW-10		.672000 MG/L
			SW-9		.478000 MG/L
					.484000 MG/L
	Mercury	ESE, Jan 1991 (Table G-10)	GW-1-2		.000200 MG/L
			GW-3-2		.000200 MG/L
			GW-4-2		.000300 MG/L
			SW-1-2		.000200 MG/L
			SW-3-2		.000200 MG/L
			SW-4		.000200 MG/L
			SW-4-2		.000200 MG/L
		ESE, Oct 1992 (Table G-11)	DW-1		.000100 MG/L
			DW-2		.000100 MG/L
			SW-2		.000100 MG/L
			SW-5		.000100 MG/L
	Methylene chloride	ESE, Oct 1990 (Table G-7)	GW-1-1	<	.012000 MG/L
			GW-1-2	<	.005000 MG/L
			SW-4-1		.009000 MG/L
	Nickel	ESE, Jan 1991 (Table G-10)	GW-1-2		.010000 MG/L
			GW-3-2		.015000 MG/L
			GW-4-2		.031000 MG/L
			SW-1-2		.021000 MG/L
			SW-3-2		.011000 MG/L
			SW-4-2		.087000 MG/L
		ESE, Oct 1992 (Table G-11)	DW-1		.012200 MG/L
			DW-2		.012200 MG/L
			SW-2		.012200 MG/L
			SW-5		.012200 MG/L
	Potassium	Baker, May 1995	DW-3		105.000000 MG/L
			DW-4		142.000000 MG/L
			DW-5		205.000000 MG/L
			DW-6		237.000000 MG/L

Medium	Chemname	Source	Sampid	Conc	Units
Groundwater	Potassium	Baker, May 1995	DW-7	80.300000	MG/L
			DW-8	62.500000	MG/L
			SW-10	107.000000	MG/L
			SW-9	93.200000	MG/L
				95.100000	MG/L
	Selenium	ESE, Jan 1991 (Table G-10)	GW-1-2	.002000	MG/L
			GW-3-2	.001000	MG/L
			GW-4-2	.005000	MG/L
			SW-1-2	.002000	MG/L
			SW-3-2	.002000	MG/L
			SW-4	.090000	MG/L
			SW-4-2	.010000	MG/L
		ESE, Oct 1992 (Table G-11)	DW-1	.001500	MG/L
			DW-2	.001500	MG/L
			SW-2	.001500	MG/L
			SW-5	.001500	MG/L
		ESE, Jan 1991 (Table G-10)	GW-1-2	.004000	MG/L
			GW-3-2	.004000	MG/L
			GW-4-2	.004000	MG/L
			SW-1-2	.007000	MG/L
			SW-3-2	.007000	MG/L
			SW-4	.012000	MG/L
			SW-4-2	.007000	MG/L
		ESE, Oct 1992 (Table G-11)	DW-1	.004600	MG/L
			DW-2	.002700	MG/L
			SW-2	.002700	MG/L
			SW-5	.002700	MG/L
	Sodium	Baker, May 1995	DW-3	3690.000000	MG/L
			DW-4	5450.000000	MG/L
			DW-5	6290.000000	MG/L
			DW-6	6660.000000	MG/L
			DW-7	2160.000000	MG/L
			DW-8	793.000000	MG/L
			SW-10	2330.000000	MG/L
			SW-9	2350.000000	MG/L
				2360.000000	MG/L
	Tetrachloroethene	Baker, May 1995	DW-3	< .010000	MG/L
			DW-4	< .010000	MG/L
			DW-5	< .010000	MG/L
			DW-6	< .010000	MG/L
			DW-7	< .010000	MG/L
			DW-8	.075000	MG/L
			SW-10	< .010000	MG/L
			SW-9	< .010000	MG/L
				< .010000	MG/L
		ESE, Dec 1992 (Table 5-3)	HP-10-15	< .001000	MG/L
			HP-10-15D	< .001000	MG/L
			HP-10-25	.010600	MG/L
			HP-10-35	< .001000	MG/L
			HP-10-45	< .001000	MG/L
			HP-11-15	.026900	MG/L
			HP-11-25	.013500	MG/L
			HP-11-35	< .010000	MG/L
			HP-11-45	< .010000	MG/L
			HP-11-55	< .001000	MG/L
			HP-11-65	< .001000	MG/L
			HP-11-75	< .001000	MG/L
			HP-13-15	.010900	MG/L
			HP-13-25	< .001000	MG/L
			HP-13-35	< .001000	MG/L
			HP-15-15	.155000	MG/L
			HP-15-25	< .001000	MG/L
			HP-15-35	< .001000	MG/L
			HP-15-45	< .001000	MG/L
			HP-15-55	< .001000	MG/L
			HP-17-15	.074000	MG/L
			HP-17-25	.019000	MG/L
			HP-17-35	< .001000	MG/L
		ESE, Jan 1993 (Table G-8)	SW-10-D	.001200	MG/L
			SW-10-S	< .001000	MG/L
			SW-9-D	.003600	MG/L
			SW-9-S	.010500	MG/L

Medium	Chemname	Source	Sampid	Conc	Units
Groundwater	Thallium	Baker, May 1995	DW-3	<	.003500 MG/L
			DW-4	<	.006000 MG/L
			DW-5	<	.003500 MG/L
			DW-6	<	.005500 MG/L
			DW-7	<	.000700 MG/L
			DW-8	<	.000700 MG/L
			SW-10	<	.003500 MG/L
			SW-9	<	.000700 MG/L
				<	.000700 MG/L
	Trichloroethane, 1,1,1-	ESE, Oct 1990 (Table G-7)	DW-1		.003000 MG/L
			GW-1-1	<	.012000 MG/L
			GW-1-2	<	.005000 MG/L
			SW-1-1		1.100000 MG/L
			SW-1-1FD		.660000 MG/L
			SW-1-2		.690000 MG/L
			SW-2-1		.390000 MG/L
			SW-2-2		.270000 MG/L
			SW-4-1		.003000 MG/L
			SW-4-2		.003000 MG/L
			SW-6-1		.001000 MG/L
			SW-6-2	<	.250000 MG/L
Groundwater	Trichloroethene	Baker, May 1995	DW-3	<	.010000 MG/L
			DW-4	<	.010000 MG/L
			DW-5	<	.010000 MG/L
			DW-6	<	.010000 MG/L
			DW-7		.020000 MG/L
			DW-8		.018000 MG/L
			SW-10	<	.010000 MG/L
			SW-9	<	.010000 MG/L
				<	.010000 MG/L
		ESE, Dec 1992 (Table 5-3)	HP-10-15		.013000 MG/L
			HP-10-15D		.012000 MG/L
			HP-10-25		.053000 MG/L
			HP-10-35		.003300 MG/L
			HP-10-45	<	.001000 MG/L
			HP-11-15		.299000 MG/L
			HP-11-25		.233000 MG/L
			HP-11-35		.866000 MG/L
			HP-11-45		.057700 MG/L
			HP-11-55		.032700 MG/L
			HP-11-65		.018700 MG/L
			HP-11-75	<	.001000 MG/L
			HP-13-15		.082700 MG/L
			HP-13-25		.003500 MG/L
			HP-13-35	<	.001000 MG/L
	Vinyl chloride	ESE, Jan 1993 (Table G-8).	SW-10-D		.022400 MG/L
			SW-10-S		.004500 MG/L
			SW-9-D		.003000 MG/L
			SW-9-S		.010000 MG/L
		ESE, Oct 1990 (Table G-7)	DW-1	<	.010000 MG/L
			GW-1-1		.034000 MG/L
			GW-1-2	<	.010000 MG/L
			SW-1-1	<	.250000 MG/L
			SW-1-1FD	<	.050000 MG/L
			SW-1-2	<	.250000 MG/L
			SW-2-1	<	.500000 MG/L
			SW-2-2	<	.500000 MG/L
			SW-4-1	<	.010000 MG/L
			SW-4-2	<	.010000 MG/L
			SW-6-1	<	.010000 MG/L
			SW-6-2	<	.500000 MG/L
Groundwater	Zinc	Baker, May 1995	DW-3		.021500 MG/L
			DW-4		.030500 MG/L
			DW-5		.037600 MG/L
			DW-6		.032000 MG/L
			DW-8		.020600 MG/L
			SW-9		.026000 MG/L

Medium	Chemname	Source	Sampid	Conc	Units
Groundwater	Zinc	ESE, Jan 1991 (Table G-10)	GW-1-2	.027000	MG/L
			GW-3-2	.042000	MG/L
			GW-4-2	.101000	MG/L
			SW-1-2	.033000	MG/L
			SW-3-2	.011000	MG/L
			SW-4-2	.416000	MG/L
		ESE, Oct 1992 (Table G-11)	DW-1	.001000	MG/L
			DW-2	.001000	MG/L
			SW-2	.004500	MG/L
			SW-5	.001000	MG/L
Soil	Acenaphthene	Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-06	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-08	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
					2.000000 MG/KG
	Acetone	ESE, Sep 1990 (Table G-1)	EY-2-1	<	.011000 MG/KG
			EY-2-2	<	.011000 MG/KG
			EY-3-1	<	.011000 MG/KG
			EY-3-2	<	.011000 MG/KG
			EY-4-1	<	.011000 MG/KG
			EY-4-2	<	.011000 MG/KG
			EY-5-1	<	.011000 MG/KG
			EY-5-2	<	.011000 MG/KG
			EY-5-2FD	<	.011000 MG/KG
			EY-7-1	<	.011000 MG/KG
			EY-7-2	<	.007000 MG/KG
			HM-10-1	<	.010000 MG/KG
			HM-10-2	<	.011000 MG/KG
			HM-2-1	<	.011000 MG/KG
			HM-2-2	<	.011000 MG/KG
			HM-3-1	<	.011000 MG/KG
			HM-3-2	<	.057000 MG/KG
			HM-4-1	<	.027000 MG/KG
			HM-4-1FD	<	.028000 MG/KG
			HM-4-2	<	.008000 MG/KG
			HM-5-1	<	.011000 MG/KG
			HM-5-2	<	.012000 MG/KG
			HM-7-1	<	.011000 MG/KG
			HM-7-2	<	.011000 MG/KG
			HM-9-1	<	.010000 MG/KG
			PP-11-1	<	.011000 MG/KG
			PP-11-2	<	.014000 MG/KG
			PP-12-1	<	.011000 MG/KG
			PP-12-2	<	.011000 MG/KG
			PP-14-1	<	.011000 MG/KG
			PP-14-2	<	.011000 MG/KG
			PP-14-2FD	<	.011000 MG/KG
			PP-2-1	<	.054000 MG/KG
			PP-2-2	<	.011000 MG/KG
			PP-3-1	<	.011000 MG/KG
			PP-3-1FD	<	.010000 MG/KG
			PP-3-1RE	<	.011000 MG/KG
			PP-3-2	<	.011000 MG/KG
			PP-5-1	<	.006000 MG/KG
			PP-5-2	<	.007000 MG/KG
			PP-6-1	<	.012000 MG/KG
			PP-6-2	<	.025000 MG/KG
			PP-8-1	<	.011000 MG/KG
			PP-8-2	<	.120000 MG/KG
			PP-9-1	<	.008000 MG/KG
			PP-9-2	<	.006000 MG/KG
			SW-1	<	.450000 MG/KG
			SW-2	<	.450000 MG/KG
			SW-3	<	.150000 MG/KG
			TA-1-1	<	.650000 MG/KG
			TA-1-2	<	.023000 MG/KG
			TA-1-2FD	<	.011000 MG/KG
			TA-3-1	<	.059000 MG/KG

Medium	Chemname	Source	Sampled	Conc	Units
Soil	Acetone	ESE, Sep 1990 (Table G-1)	TA-3-2	.370000	MG/KG
			TA-3-2RE	.340000	MG/KG
			TA-5-1	.540000	MG/KG
			TA-5-2	.440000	MG/KG
	Aldrin	Baker, May 1995	SS-17	< .001800	MG/KG
				< .001800	MG/KG
			SS-18	.001400	MG/KG
	Aluminum	Baker, May 1995	SS-17	5470.000000	MG/KG
				5550.000000	MG/KG
			SS-18	3680.000000	MG/KG
			SS-19	4060.000000	MG/KG
	Antimony	Baker, May 1995	SS-17	< 1.900000	MG/KG
				< 2.100000	MG/KG
			SS-18	3.200000	MG/KG
			SS-19	< 2.000000	MG/KG
	Arsenic	Baker, May 1995	SS-20	< 2.400000	MG/KG
		Malcolm Pirnie, 1983-1986	SS-17	10.500000	MG/KG
				11.200000	MG/KG
			SS-18	11.700000	MG/KG
			SS-19	9.700000	MG/KG
			SS-20	13.200000	MG/KG
			03S-05	< .050000	MG/KG
				14.000000	MG/KG
				23.000000	MG/KG
			03S-06	5.300000	MG/KG
				8.400000	MG/KG
				21.000000	MG/KG
			03S-07	4.700000	MG/KG
				6.500000	MG/KG
				14.000000	MG/KG
			03S-08	6.200000	MG/KG
				21.000000	MG/KG
				32.000000	MG/KG
	Barium	Baker, May 1995	SS-17	38.100000	MG/KG
				39.700000	MG/KG
			SS-18	53.800000	MG/KG
			SS-19	34.200000	MG/KG
	Benz(a)anthracene	Baker, May 1995	SS-20	56.600000	MG/KG
		Malcolm Pirnie, 1983-1986	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	.082000	MG/KG
			03S-05	< .200000	MG/KG
				< .200000	MG/KG
				.260000	MG/KG
			03S-06	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
			03S-07	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
			03S-08	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
	Benzene	ESE, Sep 1990 (Table G-1)	EY-2-1	< .005000	MG/KG
			EY-2-2	< .005000	MG/KG
			EY-3-1	< .005000	MG/KG
			EY-3-2	.002000	MG/KG
			EY-4-1	< .005000	MG/KG
			EY-4-2	< .005000	MG/KG
			EY-5-1	< .005000	MG/KG
			EY-5-2	< .005000	MG/KG
			EY-5-2FD	< .005000	MG/KG
			EY-7-1	< .005000	MG/KG
			EY-7-2	< .006000	MG/KG
			HM-10-1	< .005000	MG/KG
			HM-10-2	< .005000	MG/KG
			HM-2-1	< .005000	MG/KG
			HM-2-2	< .005000	MG/KG
			HM-3-1	< .005000	MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Benzene	ESE, Sep 1990 (Table G-1)	HM-3-2	< .005000	MG/KG
			HM-4-1	< .005000	MG/KG
			HM-4-1FD	< .005000	MG/KG
			HM-4-2	< .006000	MG/KG
			HM-5-1	< .005000	MG/KG
			HM-5-2	< .006000	MG/KG
			HM-7-1	< .005000	MG/KG
			HM-7-2	< .005000	MG/KG
			HM-9-1	< .005000	MG/KG
			PP-11-1	< .005000	MG/KG
			PP-11-2	< .005000	MG/KG
			PP-12-1	< .005000	MG/KG
			PP-12-2	< .005000	MG/KG
			PP-14-1	< .005000	MG/KG
			PP-14-2	< .005000	MG/KG
			PP-14-2FD	< .005000	MG/KG
			PP-2-1	< .027000	MG/KG
			PP-2-2	< .005000	MG/KG
			PP-3-1	< .005000	MG/KG
			PP-3-1FD	< .005000	MG/KG
			PP-3-1RE	< .005000	MG/KG
			PP-3-2	< .005000	MG/KG
			PP-5-1	< .005000	MG/KG
			PP-5-2	< .005000	MG/KG
			PP-6-1	< .005000	MG/KG
			PP-6-2	< .005000	MG/KG
			PP-8-1	< .005000	MG/KG
			PP-8-2	< .005000	MG/KG
			PP-9-1	< .005000	MG/KG
			PP-9-2	< .006000	MG/KG
			SW-1	< .007000	MG/KG
			SW-2	< .007000	MG/KG
			SW-3	< .006000	MG/KG
			TA-1-1	< .005000	MG/KG
			TA-1-2	< .005000	MG/KG
			TA-1-2FD	< .005000	MG/KG
			TA-3-1	< .005000	MG/KG
			TA-3-2	< .005000	MG/KG
			TA-3-2RE	< .005000	MG/KG
			TA-6-1	< .005000	MG/KG
			TA-6-2	< .006000	MG/KG
	Benzo(a)pyrene	Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	< .085000	MG/KG
	Benzo(b)fluoranthene	Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	< .130000	MG/KG
	Benzo(ghi)perylene	Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	< .078000	MG/KG
	Benzo(k)fluoranthene	Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	< .061000	MG/KG
	BHC, beta-	Baker, May 1995	SS-17	.003600	MG/KG
			SS-18	< .004000	MG/KG
	BHC, delta-	Baker, May 1995		< .001700	MG/KG
			SS-17	.001100	MG/KG
				< .001800	MG/KG
	BHC, gamma- (Lindane)	Baker, May 1995	SS-18	< .001700	MG/KG
			SS-17	.001100	MG/KG
				< .001800	MG/KG
	Bis(2-ethylhexyl) phthalate	Baker, May 1995	SS-18	< .001700	MG/KG
			SS-17	.001100	MG/KG
				< 3.600000	MG/KG
				< 7.200000	MG/KG
				< 6.900000	MG/KG



Medium	Chemname	Source	Sampid	Conc	Units
Soil	Bis(2-ethylhexyl) phthalate	Baker, May 1995	SS-19	.047000	MG/KG
			SS-20	.100000	MG/KG
	Butylbenzyl phthalate	Malcolm Pirnie, 1983-1986	03S-09	< .330000	MG/KG
				< .330000	MG/KG
			03S-09A	< .330000	MG/KG
			03S-10	< .330000	MG/KG
				< .330000	MG/KG
				< .330000	MG/KG
			03S-11	< .330000	MG/KG
				< .330000	MG/KG
				.530000	MG/KG
			03S-12	< .330000	MG/KG
				< .330000	MG/KG
				< .330000	MG/KG
			03S-13	< .330000	MG/KG
				< .330000	MG/KG
				< .330000	MG/KG
			03S-14	< .330000	MG/KG
				< .330000	MG/KG
				< .330000	MG/KG
			03S-15	< .330000	MG/KG
				< .330000	MG/KG
				< .330000	MG/KG
	Cadmium (solid matrix)	Malcolm Pirnie, 1983-1986	03S-05	1.200000	MG/KG
				1.400000	MG/KG
				2.000000	MG/KG
			03S-06	.500000	MG/KG
				.600000	MG/KG
				1.000000	MG/KG
			03S-07	.500000	MG/KG
				1.300000	MG/KG
	Calcium	Baker, May 1995	SS-17	*****	MG/KG
				*****	MG/KG
			SS-18	*****	MG/KG
			SS-19	*****	MG/KG
	Chlordane, alpha-	Baker, May 1995	SS-20	*****	MG/KG
			SS-17	< .001800	MG/KG
				< .001800	MG/KG
			SS-18	.003100	MG/KG
	Chlordane, gamma-	Baker, May 1995	SS-19	.007700	MG/KG
			SS-20	.012000	MG/KG
			SS-17	< .001800	MG/KG
				< .001800	MG/KG
	Chromium, total	Baker, May 1995	SS-18	.004900	MG/KG
			SS-19	.010000	MG/KG
			SS-20	.014000	MG/KG
			SS-17	13.900000	MG/KG
	Chrysene	Baker, May 1995		16.600000	MG/KG
			SS-18	13.400000	MG/KG
			SS-19	17.200000	MG/KG
			SS-20	19.900000	MG/KG
		Malcolm Pirnie, 1983-1986	03S-05	8.000000	MG/KG
				10.000000	MG/KG
				16.000000	MG/KG
			03S-06	8.400000	MG/KG
				9.700000	MG/KG
				20.000000	MG/KG
			03S-07	6.400000	MG/KG
				12.000000	MG/KG
				12.000000	MG/KG
			03S-08	8.400000	MG/KG
				16.000000	MG/KG
				17.000000	MG/KG
		Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	.110000	MG/KG

Medium	Chemname	Source	Sampled	Conc	Units
Soil	Chrysene	Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
			03S-06	<	.260000 MG/KG
				<	.200000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG
			03S-08	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
	Copper	Baker, May 1995	SS-17		9.800000 MG/KG
					12.000000 MG/KG
			SS-18		24.300000 MG/KG
			SS-19		12.300000 MG/KG
			SS-20		21.000000 MG/KG
		Malcolm Pirnie, 1983-1986	03S-05		1.200000 MG/KG
					5.100000 MG/KG
			03S-06		5.600000 MG/KG
					.500000 MG/KG
			03S-07		.600000 MG/KG
					5.200000 MG/KG
			03S-08		1.300000 MG/KG
					2.000000 MG/KG
					4.700000 MG/KG
					1.800000 MG/KG
	DDD, p,p'-	Baker, May 1995	SS-17		.003200 MG/KG
					.010000 MG/KG
			SS-18		.003800 MG/KG
			SS-20	<	.003600 MG/KG
		Malcolm Pirnie, 1983-1986	03S-05	<	.002000 MG/KG
				<	.002000 MG/KG
			03S-06	<	.002000 MG/KG
				<	.002000 MG/KG
			03S-07	<	.002000 MG/KG
				<	.003700 MG/KG
			03S-08		.130000 MG/KG
					.160000 MG/KG
	DDE, p,p'-	Baker, May 1995	SS-17		.002200 MG/KG
				<	.003600 MG/KG
			SS-18	<	.003500 MG/KG
			SS-20		.001800 MG/KG
		Malcolm Pirnie, 1983-1986	03S-05	<	.002000 MG/KG
				<	.002000 MG/KG
			03S-06	<	.002000 MG/KG
				<	.002000 MG/KG
			03S-07	<	.002000 MG/KG
				<	.002000 MG/KG
	DDT, p,p'-	Malcolm Pirnie, 1983-1986	03S-05	<	.002000 MG/KG
				<	.002000 MG/KG
			03S-06	<	.002000 MG/KG
				<	.002000 MG/KG
			03S-07	<	.002000 MG/KG
				<	.002000 MG/KG
			03S-08	<	.005400 MG/KG
				<	.005700 MG/KG
				<	.002000 MG/KG
				<	.002000 MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Di-n-butyl phthalate	Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-06	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-08	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
					2.000000 MG/KG
	Dichlorobenzene, 1,4-	Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-06	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-08	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
					2.000000 MG/KG
	Dichloroethene, 1,1-	ESE, Sep 1990 (Table G-1)	EY-2-1	<	.005000 MG/KG
			EY-2-2	<	.005000 MG/KG
			EY-3-1	<	.005000 MG/KG
			EY-3-2	<	.005000 MG/KG
			EY-4-1	<	.005000 MG/KG
			EY-4-2	<	.005000 MG/KG
			EY-5-1	<	.005000 MG/KG
			EY-5-2	<	.005000 MG/KG
			EY-5-2FD	<	.005000 MG/KG
			EY-7-1	<	.005000 MG/KG
			EY-7-2	<	.006000 MG/KG
			HM-10-1	<	.005000 MG/KG
			HM-10-2	<	.005000 MG/KG
			HM-2-1	<	.005000 MG/KG
			HM-2-2	<	.005000 MG/KG
			HM-3-1	<	.005000 MG/KG
			HM-3-2	<	.005000 MG/KG
			HM-4-1	<	.005000 MG/KG
			HM-4-1FD	<	.005000 MG/KG
			HM-4-2	<	.006000 MG/KG
			HM-5-1	<	.005000 MG/KG
			HM-5-2	<	.006000 MG/KG
			HM-7-1	<	.005000 MG/KG
			HM-7-2	<	.005000 MG/KG
			HM-9-1	<	.005000 MG/KG
			PP-11-1	<	.005000 MG/KG
			PP-11-2	<	.005000 MG/KG
			PP-12-1	<	.005000 MG/KG
			PP-12-2	<	.005000 MG/KG
			PP-14-1	<	.005000 MG/KG
			PP-14-2	<	.005000 MG/KG
			PP-14-2FD	<	.005000 MG/KG
			PP-2-1	<	.027000 MG/KG
			PP-2-2	<	.005000 MG/KG
			PP-3-1	<	.005000 MG/KG
			PP-3-1FD	<	.005000 MG/KG
			PP-3-1RE	<	.005000 MG/KG
			PP-3-2	<	.005000 MG/KG
			PP-5-1	<	.005000 MG/KG
			PP-5-2	<	.005000 MG/KG
			PP-6-1	<	.005000 MG/KG
			PP-6-2	<	.005000 MG/KG
			PP-8-1	<	.005000 MG/KG
			PP-8-2	<	.005000 MG/KG
			PP-9-1	<	.005000 MG/KG
			PP-9-2	<	.006000 MG/KG
			SW-1	<	.007000 MG/KG
			SW-2	<	.005000 MG/KG
			SW-3	<	.006000 MG/KG
			TA-1-1	<	.005000 MG/KG
			TA-1-2	<	.005000 MG/KG
			TA-1-2FD	<	.005000 MG/KG
			TA-3-1	<	.005000 MG/KG
			TA-3-2	<	.005000 MG/KG
			TA-3-2RE	<	.005000 MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Dichloroethene, 1,1-	ESE, Sep 1990 (Table G-1)	TA-5-1	<	.005000 MG/KG
			TA-5-2	<	.006000 MG/KG
	Dichloroethenes, 1,2-, total	ESE, Sep 1990 (Table G-1)	EY-2-1	<	.005000 MG/KG
			EY-2-2	<	.005000 MG/KG
			EY-3-1	<	.005000 MG/KG
			EY-3-2	<	.005000 MG/KG
			EY-4-1	<	.005000 MG/KG
			EY-4-2	<	.005000 MG/KG
			EY-5-1	<	.005000 MG/KG
			EY-5-2	<	.005000 MG/KG
			EY-5-2FD	<	.005000 MG/KG
			EY-7-1	<	.005000 MG/KG
			EY-7-2	<	.006000 MG/KG
			HM-10-1	<	.005000 MG/KG
			HM-10-2	<	.005000 MG/KG
			HM-2-1	<	.005000 MG/KG
			HM-2-2	<	.005000 MG/KG
			HM-3-1	<	.020000 MG/KG
			HM-3-2	<	.005000 MG/KG
			HM-4-1	<	.005000 MG/KG
			HM-4-1FD	<	.005000 MG/KG
			HM-4-2	<	.006000 MG/KG
			HM-5-1	<	.005000 MG/KG
			HM-5-2	<	.016000 MG/KG
			HM-7-1	<	.015000 MG/KG
			HM-7-2	<	.005000 MG/KG
			HM-9-1	<	.005000 MG/KG
			PP-11-1	<	.005000 MG/KG
			PP-11-2	<	.005000 MG/KG
			PP-12-1	<	.005000 MG/KG
			PP-12-2	<	.005000 MG/KG
			PP-14-1	<	.005000 MG/KG
			PP-14-2	<	.005000 MG/KG
			PP-14-2FD	<	.005000 MG/KG
			PP-2-1	<	1.500000 MG/KG
			PP-2-2	<	.005000 MG/KG
			PP-3-1	<	.005000 MG/KG
			PP-3-1FD	<	.005000 MG/KG
			PP-3-1RE	<	.005000 MG/KG
			PP-3-2	<	.005000 MG/KG
			PP-5-1	<	.005000 MG/KG
			PP-5-2	<	.005000 MG/KG
			PP-6-1	<	.005000 MG/KG
			PP-6-2	<	.005000 MG/KG
			PP-8-1	<	.005000 MG/KG
			PP-8-2	<	.005000 MG/KG
			PP-9-1	<	.005000 MG/KG
			PP-9-2	<	.006000 MG/KG
			SW-1	<	.007000 MG/KG
			SW-2	<	.007000 MG/KG
			SW-3	<	.006000 MG/KG
			TA-1-1	<	.005000 MG/KG
			TA-1-2	<	.005000 MG/KG
			TA-1-2FD	<	.005000 MG/KG
			TA-3-1	<	.005000 MG/KG
			TA-3-2	<	.005000 MG/KG
			TA-3-2RE	<	.005000 MG/KG
			TA-5-1	<	.005000 MG/KG
			TA-5-2	<	.006000 MG/KG
	Dimethylphenol, 2,4-	Malcolm Pirnie, 1983-1986	03S-05	<	.500000 MG/KG
				<	.500000 MG/KG
			03S-06	<	.500000 MG/KG
				<	.500000 MG/KG
			03S-07	<	.720000 MG/KG
				<	.500000 MG/KG
			03S-08	<	4.800000 MG/KG
				<	.500000 MG/KG
				<	.500000 MG/KG
				<	.500000 MG/KG
	Dinitrotoluene, 2,4-	Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-06	<	.200000 MG/KG
				<	.200000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Dinitrotoluene, 2,4-	Malcolm Pirnie, 1983-1986	03S-07	< .200000	MG/KG
				< .200000	MG/KG
			03S-08	< .200000	MG/KG
				< .200000	MG/KG
	Endosulfan sulfate	Malcolm Pirnie, 1983-1986		1.800000	MG/KG
			03S-05	< .002000	MG/KG
				< .002000	MG/KG
				< .002000	MG/KG
			03S-06	< .002000	MG/KG
				< .002000	MG/KG
				< .002000	MG/KG
			03S-07	< .002000	MG/KG
				< .002000	MG/KG
				< .002000	MG/KG
			03S-08	< .002000	MG/KG
				< .002000	MG/KG
	Fluoranthene	Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
		Malcolm Pirnie, 1983-1986	SS-20	.170000	MG/KG
			03S-05	< .200000	MG/KG
				< .200000	MG/KG
				.700000	MG/KG
			03S-06	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
			03S-07	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
			03S-08	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
	Indeno(1,2,3-cd)pyrene	Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	.083000	MG/KG
Iron	Baker, May 1995		SS-17	*****	MG/KG
				*****	MG/KG
			SS-18	*****	MG/KG
			SS-19	*****	MG/KG
			SS-20	*****	MG/KG
Lead	Baker, May 1995		SS-17	15.900000	MG/KG
				17.000000	MG/KG
			SS-18	105.000000	MG/KG
			SS-19	17.000000	MG/KG
			SS-20	50.600000	MG/KG
	Malcolm Pirnie, 1983-1986		03S-05	7.600000	MG/KG
				28.000000	MG/KG
				34.000000	MG/KG
			03S-06	5.400000	MG/KG
				8.300000	MG/KG
				23.000000	MG/KG
			03S-07	13.000000	MG/KG
				13.000000	MG/KG
			03S-08	32.000000	MG/KG
				7.000000	MG/KG
				9.200000	MG/KG
				21.000000	MG/KG
Magnesium	Baker, May 1995		SS-17	3380.000000	MG/KG
				3410.000000	MG/KG
			SS-18	5500.000000	MG/KG
			SS-19	3470.000000	MG/KG
			SS-20	3120.000000	MG/KG
Manganese	Baker, May 1995		SS-17	286.000000	MG/KG
				362.000000	MG/KG
			SS-18	245.000000	MG/KG
			SS-19	251.000000	MG/KG
			SS-20	287.000000	MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Mercury	Malcolm Pirnie, 1983-1986	03S-05	.060000	MG/KG
				.080000	MG/KG
				.140000	MG/KG
			03S-06	.030000	MG/KG
				.060000	MG/KG
				.080000	MG/KG
			03S-07	.030000	MG/KG
				.110000	MG/KG
				.240000	MG/KG
			03S-08	.025000	MG/KG
				.030000	MG/KG
				.045000	MG/KG
	Methylene chloride	ESE, Sep 1990 (Table G-1)	HM-10-2	<	.005000 MG/KG
			HM-2-2	<	.005000 MG/KG
			HM-3-1		.003000 MG/KG
			HM-3-2	<	.005000 MG/KG
			HM-4-1	<	.005000 MG/KG
			HM-4-2	<	.006000 MG/KG
			PP-11-1		.009000 MG/KG
			PP-11-2		.024000 MG/KG
			PP-14-1		.034000 MG/KG
			PP-2-1		.039000 MG/KG
			PP-2-2	<	.005000 MG/KG
			PP-3-1		.028000 MG/KG
			PP-3-1FD	<	.005000 MG/KG
			PP-3-1RE		.018000 MG/KG
			PP-3-2	<	.005000 MG/KG
			PP-5-1		.004000 MG/KG
			PP-5-2	<	.005000 MG/KG
			PP-6-1		.022000 MG/KG
			PP-6-2		.020000 MG/KG
			SW-2	<	.007000 MG/KG
			SW-3		.009000 MG/KG
			TA-3-2	<	.005000 MG/KG
	Nickel	Baker, May 1995	SS-17	6.300000	MG/KG
				7.900000	MG/KG
			SS-18	10.200000	MG/KG
			SS-19	14.800000	MG/KG
			SS-20	11.800000	MG/KG
		Malcolm Pirnie, 1983-1986	03S-05	2.400000	MG/KG
				5.100000	MG/KG
				5.300000	MG/KG
			03S-06	1.200000	MG/KG
				1.400000	MG/KG
				4.200000	MG/KG
			03S-07	1.500000	MG/KG
				1.700000	MG/KG
				5.100000	MG/KG
			03S-08	1.800000	MG/KG
				2.400000	MG/KG
				22.000000	MG/KG
	Nitrosodi-N-propylamine, N-	Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-06	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-08	<	.200000 MG/KG
				<	.200000 MG/KG
				<	10.000000 MG/KG
	Phenanthrene	Baker, May 1995	SS-17	<	3.600000 MG/KG
				<	7.200000 MG/KG
			SS-18	<	6.900000 MG/KG
			SS-19	<	.350000 MG/KG
			SS-20		.092000 MG/KG
		Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.600000 MG/KG
			03S-06	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.380000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG

Medium	Chemname	Source	Sampled	Conc	Units
Soil	Phenanthrene	Malcolm Pirnie, 1983-1986	03S-07	< .200000	MG/KG
				< .200000	MG/KG
			03S-08	< .200000	MG/KG
				< .200000	MG/KG
		Baker, May 1995	SS-17	2.700000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	< .360000	MG/KG
		Malcolm Pirnie, 1983-1986	03S-05	< .500000	MG/KG
				< .500000	MG/KG
				< .500000	MG/KG
			03S-06	< .500000	MG/KG
				2.200000	MG/KG
				3.400000	MG/KG
			03S-07	< .500000	MG/KG
				< .500000	MG/KG
				< .500000	MG/KG
			03S-08	< .500000	MG/KG
				< .500000	MG/KG
				< .500000	MG/KG
	Potassium	Baker, May 1995	SS-17	2310.000000	MG/KG
				2800.000000	MG/KG
			SS-18	1220.000000	MG/KG
			SS-19	1760.000000	MG/KG
			SS-20	1890.000000	MG/KG
	Pyrene	Baker, May 1995	SS-17	< 3.600000	MG/KG
				< 7.200000	MG/KG
			SS-18	< 6.900000	MG/KG
			SS-19	< .350000	MG/KG
			SS-20	< .140000	MG/KG
		Malcolm Pirnie, 1983-1986	03S-05	< .200000	MG/KG
				< .500000	MG/KG
				< .520000	MG/KG
			03S-06	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
			03S-07	< .200000	MG/KG
				< .200000	MG/KG
				< .200000	MG/KG
			03S-08	< .200000	MG/KG
				< .200000	MG/KG
				1.800000	MG/KG
	Silver	Malcolm Pirnie, 1983-1986	03S-05	< .060000	MG/KG
				< .060000	MG/KG
				< .060000	MG/KG
			03S-06	< .060000	MG/KG
				.300000	MG/KG
				1.000000	MG/KG
			03S-07	< .060000	MG/KG
				< .060000	MG/KG
				< .060000	MG/KG
			03S-08	< .060000	MG/KG
				< .060000	MG/KG
				< .060000	MG/KG
	Sodium	Baker, May 1995	SS-19	1140.000000	MG/KG
	Tetrachloroethene	Baker, May 1995	SS-17	.002000	MG/KG
				< .011000	MG/KG
			SS-18	< .044000	MG/KG
			SS-19	< .010000	MG/KG
			SS-20	< .011000	MG/KG
		ESE, Sep 1990 (Table G-1)	EY-2-1	.011000	MG/KG
			EY-2-2	< .005000	MG/KG
			EY-3-1	< .005000	MG/KG
			EY-3-2	< .005000	MG/KG
			EY-4-1	< .005000	MG/KG
			EY-4-2	< .005000	MG/KG
			EY-5-1	< .005000	MG/KG
			EY-5-2	< .005000	MG/KG
			EY-5-2FD	< .005000	MG/KG
			EY-7-1	< .005000	MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Tetrachloroethene	ESE, Sep 1990 (Table G-1)	EY-7-2	<	.006000 MG/KG
			HM-10-1		.150000 MG/KG
			HM-10-2	<	.005000 MG/KG
			HM-2-1	<	.005000 MG/KG
			HM-2-2	<	.005000 MG/KG
			HM-3-1		.004000 MG/KG
			HM-3-2	<	.005000 MG/KG
			HM-4-1		.010000 MG/KG
			HM-4-1FD		.017000 MG/KG
			HM-4-2		.004000 MG/KG
			HM-5-1	<	.005000 MG/KG
			HM-5-2	<	.006000 MG/KG
			HM-7-1	<	.005000 MG/KG
			HM-7-2	<	.005000 MG/KG
			HM-9-1		.096000 MG/KG
			PP-11-1	<	.005000 MG/KG
			PP-11-2	<	.005000 MG/KG
			PP-12-1		.010000 MG/KG
			PP-12-2	<	.005000 MG/KG
			PP-14-1	<	.005000 MG/KG
			PP-14-2	<	.005000 MG/KG
			PP-14-2FD	<	.005000 MG/KG
			PP-2-1		.150000 MG/KG
			PP-2-2	<	.005000 MG/KG
			PP-3-1	<	.005000 MG/KG
			PP-3-1FD	<	.005000 MG/KG
			PP-3-1RE	<	.005000 MG/KG
			PP-3-2	<	.005000 MG/KG
			PP-5-1	<	.005000 MG/KG
			PP-5-2	<	.005000 MG/KG
			PP-6-1	<	.005000 MG/KG
			PP-6-2	<	.005000 MG/KG
			PP-8-1	<	.005000 MG/KG
			PP-8-2	<	.005000 MG/KG
			PP-9-1	<	.005000 MG/KG
			PP-9-2	<	.006000 MG/KG
			SW-1		.007000 MG/KG
			SW-2		.007000 MG/KG
			SW-3	<	.006000 MG/KG
			TA-1-1		.002000 MG/KG
			TA-1-2	<	.005000 MG/KG
			TA-1-2FD	<	.005000 MG/KG
			TA-3-1	<	.005000 MG/KG
			TA-3-2	<	.005000 MG/KG
			TA-3-2RE	<	.005000 MG/KG
			TA-5-1	<	.005000 MG/KG
			TA-5-2	<	.006000 MG/KG
	Thallium	Malcolm Pirnie, 1983-1986	03S-05		2.000000 MG/KG
					12.000000 MG/KG
					22.000000 MG/KG
			03S-06		2.500000 MG/KG
					2.800000 MG/KG
					16.000000 MG/KG
			03S-07		2.000000 MG/KG
					2.000000 MG/KG
					6.000000 MG/KG
			03S-08		6.600000 MG/KG
					9.000000 MG/KG
					21.000000 MG/KG
	Toluene	Baker, May 1995	SS-17		.004000 MG/KG
				<	.011000 MG/KG
			SS-18		.005000 MG/KG
			SS-19	<	.010000 MG/KG
			SS-20	<	.011000 MG/KG
		ESE, Sep 1990 (Table G-1)	EY-2-1	<	.005000 MG/KG
			EY-2-2	<	.005000 MG/KG
			EY-3-1	<	.005000 MG/KG
			EY-3-2	<	.005000 MG/KG
			EY-4-1	<	.005000 MG/KG
			EY-4-2	<	.005000 MG/KG
			EY-5-1	<	.005000 MG/KG
			EY-5-2	<	.005000 MG/KG
			EY-5-2FD	<	.005000 MG/KG
			EY-7-1	<	.005000 MG/KG
			EY-7-2	<	.006000 MG/KG
			HM-10-1	<	.005000 MG/KG
			HM-10-2	<	.005000 MG/KG
			HM-2-1	<	.005000 MG/KG



Medium	Chemname	Source	Sampid	Conc	Units
Soil	Toluene	ESE, Sep 1990 (Table G-1)	HM-2-2	<	.005000 MG/KG
			HM-3-1	<	.005000 MG/KG
			HM-3-2	<	.005000 MG/KG
			HM-4-1	<	.005000 MG/KG
			HM-4-1FD	<	.005000 MG/KG
			HM-4-2	<	.006000 MG/KG
			HM-5-1	<	.005000 MG/KG
			HM-5-2	<	.006000 MG/KG
			HM-7-1	<	.005000 MG/KG
			HM-7-2	<	.005000 MG/KG
			HM-9-1	<	.005000 MG/KG
			PP-11-1	<	.005000 MG/KG
			PP-11-2	<	.005000 MG/KG
			PP-12-1	<	.005000 MG/KG
			PP-12-2	<	.005000 MG/KG
			PP-14-1	<	.005000 MG/KG
			PP-14-2	<	.005000 MG/KG
			PP-14-2FD	<	.005000 MG/KG
			PP-2-1	<	.140000 MG/KG
			PP-2-2	<	.005000 MG/KG
			PP-3-1	<	.005000 MG/KG
			PP-3-1FD	<	.005000 MG/KG
			PP-3-1RE	<	.005000 MG/KG
			PP-3-2	<	.005000 MG/KG
			PP-5-1	<	.005000 MG/KG
			PP-5-2	<	.005000 MG/KG
			PP-6-1	<	.005000 MG/KG
			PP-6-2	<	.005000 MG/KG
			PP-8-1	<	.005000 MG/KG
			PP-8-2	<	.005000 MG/KG
			PP-9-1	<	.005000 MG/KG
			PP-9-2	<	.006000 MG/KG
			SW-1	<	.007000 MG/KG
			SW-2	<	.007000 MG/KG
			SW-3	<	.006000 MG/KG
			TA-1-1	<	.005000 MG/KG
			TA-1-2	<	.005000 MG/KG
			TA-1-2FD	<	.005000 MG/KG
			TA-3-1	<	.005000 MG/KG
			TA-3-2	<	.005000 MG/KG
			TA-3-2RE	<	.005000 MG/KG
			TA-5-1	<	.005000 MG/KG
			TA-5-2	<	.006000 MG/KG
	Trichlorobenzene, 1,2,4-	Malcolm Pirnie, 1983-1986	03S-05	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-06	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-07	<	.200000 MG/KG
				<	.200000 MG/KG
				<	.200000 MG/KG
			03S-08	<	.200000 MG/KG
				<	.200000 MG/KG
					2.000000 MG/KG
	Trichloroethane, 1,1,1-	ESE, Sep 1990 (Table G-1).	EY-2-1	<	.005000 MG/KG
			EY-2-2	<	.005000 MG/KG
			EY-3-1	<	.005000 MG/KG
			EY-3-2	<	.005000 MG/KG
			EY-4-1	<	.005000 MG/KG
			EY-4-2	<	.005000 MG/KG
			EY-5-1	<	.005000 MG/KG
			EY-5-2	<	.005000 MG/KG
			EY-5-2FD	<	.005000 MG/KG
			EY-7-1	<	.005000 MG/KG
			EY-7-2	<	.006000 MG/KG
			HM-10-1	<	.001000 MG/KG
			HM-10-2	<	.005000 MG/KG
			HM-2-1	<	.005000 MG/KG
			HM-2-2	<	.005000 MG/KG
			HM-3-1	<	.005000 MG/KG
			HM-3-2	<	.005000 MG/KG
			HM-4-1	<	.005000 MG/KG
			HM-4-1FD	<	.005000 MG/KG
			HM-4-2	<	.006000 MG/KG
			HM-5-1	<	.005000 MG/KG
			HM-5-2	<	.006000 MG/KG
			HM-7-1	<	.005000 MG/KG
			HM-7-2	<	.005000 MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Trichloroethane, 1,1,1-	ESE, Sep 1990 (Table G-1)	HM-9-1	<	.005000 MG/KG
			PP-11-1	<	.005000 MG/KG
			PP-11-2	<	.005000 MG/KG
			PP-12-1	<	.005000 MG/KG
			PP-12-2	<	.005000 MG/KG
			PP-14-1	<	.005000 MG/KG
			PP-14-2	<	.005000 MG/KG
			PP-14-2FD	<	.005000 MG/KG
			PP-2-1	<	.027000 MG/KG
			PP-2-2	<	.005000 MG/KG
			PP-3-1	<	.005000 MG/KG
			PP-3-1FD	<	.005000 MG/KG
			PP-3-1RE	<	.005000 MG/KG
			PP-3-2	<	.005000 MG/KG
			PP-5-1	<	.005000 MG/KG
			PP-5-2	<	.005000 MG/KG
			PP-6-1	<	.005000 MG/KG
			PP-6-2	<	.005000 MG/KG
			PP-8-1	<	.005000 MG/KG
			PP-8-2	<	.005000 MG/KG
			PP-9-1	<	.005000 MG/KG
			PP-9-2	<	.006000 MG/KG
			SW-1	<	.007000 MG/KG
			SW-2	<	.007000 MG/KG
			SW-3	<	.006000 MG/KG
			TA-1-1	<	.005000 MG/KG
			TA-1-2	<	.005000 MG/KG
			TA-1-2FD	<	.005000 MG/KG
			TA-3-1	<	.005000 MG/KG
			TA-3-2	<	.005000 MG/KG
			TA-3-2RE	<	.005000 MG/KG
			TA-5-1	<	.005000 MG/KG
			TA-5-2	<	.006000 MG/KG
	Vanadium	Baker, May 1995	SS-17		29.700000 MG/KG
					32.200000 MG/KG
			SS-18		43.300000 MG/KG
			SS-19		35.800000 MG/KG
			SS-20		53.200000 MG/KG
	Xylenes, total	ESE, Sep 1990 (Table G-1)	EY-2-1	<	.005000 MG/KG
			EY-2-2	<	.005000 MG/KG
			EY-3-1	<	.005000 MG/KG
			EY-3-2	<	.005000 MG/KG
			EY-4-1	<	.005000 MG/KG
			EY-4-2	<	.005000 MG/KG
			EY-5-1	<	.005000 MG/KG
			EY-5-2	<	.005000 MG/KG
			EY-5-2FD	<	.005000 MG/KG
			EY-7-1	<	.005000 MG/KG
			EY-7-2	<	.006000 MG/KG
			HM-10-1	<	.005000 MG/KG
			HM-10-2	<	.005000 MG/KG
			HM-2-1	<	.005000 MG/KG
			HM-2-2	<	.005000 MG/KG
			HM-3-1	<	.005000 MG/KG
			HM-3-2	<	.005000 MG/KG
			HM-4-1	<	.005000 MG/KG
			HM-4-1FD	<	.005000 MG/KG
			HM-4-2	<	.006000 MG/KG
			HM-5-1	<	.005000 MG/KG
			HM-5-2	<	.006000 MG/KG
			HM-7-1	<	.005000 MG/KG
			HM-7-2	<	.005000 MG/KG
			HM-9-1	<	.005000 MG/KG
			PP-11-1	<	.005000 MG/KG
			PP-11-2	<	.005000 MG/KG
			PP-12-1	<	.005000 MG/KG
			PP-12-2	<	.005000 MG/KG
			PP-14-1	<	.005000 MG/KG
			PP-14-2	<	.005000 MG/KG
			PP-14-2FD	<	.005000 MG/KG
			PP-2-1	<	.027000 MG/KG
			PP-2-2	<	.005000 MG/KG
			PP-3-1	<	.005000 MG/KG
			PP-3-1FD	<	.005000 MG/KG
			PP-3-1RE	<	.005000 MG/KG
			PP-3-2	<	.005000 MG/KG
			PP-5-1	<	.005000 MG/KG
			PP-5-2	<	.005000 MG/KG
			PP-6-1	<	.005000 MG/KG

Medium	Chemname	Source	Sampid	Conc	Units
Soil	Xylenes, total	ESE, Sep 1990 (Table G-1)	PP-6-2	<	.005000 MG/KG
			PP-8-1	<	.005000 MG/KG
			PP-8-2	<	.005000 MG/KG
			PP-9-1	<	.005000 MG/KG
			PP-9-2	<	.006000 MG/KG
			SW-1	<	.007000 MG/KG
			SW-2	<	.007000 MG/KG
			SW-3	<	.006000 MG/KG
			TA-1-1	<	.021000 MG/KG
			TA-1-2	<	.005000 MG/KG
			TA-1-2FD	<	.005000 MG/KG
			TA-3-1	<	.005000 MG/KG
			TA-3-2	<	.005000 MG/KG
			TA-3-2RE	<	.005000 MG/KG
			TA-5-1	<	.005000 MG/KG
			TA-5-2	<	.006000 MG/KG
	Zinc	Baker, May 1995	SS-17		43.300000 MG/KG
					47.200000 MG/KG
			SS-18		54.700000 MG/KG
			SS-19		40.900000 MG/KG
			SS-20		100.000000 MG/KG
		Malcolm Pirnie, 1983-1986	03S-05		11.000000 MG/KG
					42.000000 MG/KG
					53.000000 MG/KG
			03S-06		9.100000 MG/KG
					9.700000 MG/KG
					28.000000 MG/KG
			03S-07		11.000000 MG/KG
					12.000000 MG/KG
					30.000000 MG/KG
			03S-08		10.000000 MG/KG
					15.000000 MG/KG
					30.000000 MG/KG

## **Appendix K**

### **Exposure Equations and Parameters**

## HUMAN INTAKE ESTIMATION: METHODS AND EXPOSURE FACTORS

### **1.0 INTRODUCTION**

ESE uses internally-generated software called the Automated Risk Evaluation System (ARES) to estimate the exposure of various receptors to environmental chemicals and the risks associated with those exposures. Using ARES Version 3.0, designed within the SAS/STAT Version 6.03 structure, daily chemical exposures are calculated for each completed pathway for each potential receptor using appropriate exposure formulas and factors presented in various EPA guidance documents, including the Risk Assessment Guidance for Superfund (RAGS), Human Health Evaluation Manual, Part A (EPA, 1989b), Part B (EPA, 1991a), and Supplemental Guidance (EPA, 1991b); Dermal Exposure Assessment: Principles and Applications (EPA, 1992); and other EPA guidance. Where appropriate, exposure factors based on site-specific information are used in place of EPA standard default values. After determining daily exposures, ARES calculates the potential carcinogenic and noncarcinogenic risks associated with those exposures using appropriate risk reference doses (RfDs) and cancer slope factors (CSFs) available from various EPA sources, including the Integrated Risk Information System (IRIS, 1996), Health Effects Assessment Summary Tables (HEAST) (EPA, 1995a), and the EPA-NCEA Superfund Health Risk Technical Support Center (values presented in EPA, 1995b). Where no RfD is available, a provisional value is calculated using an EPA Maximum Contaminant Level (MCL) or health advisory, if available, or chronic animal data (with appropriate uncertainty factors). The following documentation provides a list of the exposure scenarios (Section 2.0), the exposure formulas (Section 3.0), and the exposure factors (Section 4.0) used to calculate the chemical intakes for the Q Area Drum Storage Yard (QADSY), as well as the references used to develop ARES (Section 5.0).

### **2.0 APPLICABLE EXPOSURE SCENARIOS**

Due to the remote nature of the site, the only human receptors currently expected to frequent the site are persons working on the peninsula. Therefore, an intermittent current worker is anticipated to be the only current exposure scenario applicable at QADSY. To assess potential worst-case conditions, future worker and future residential scenarios will be evaluated. Current and future workers and future residents may be exposed by direct contact with contaminated site soils, incidental ingestion of site soils by hand-to-mouth contact, and inhalation of chemicals in building air that have volatilized from groundwater. Repeated inhalation exposure to soils is not anticipated as site soils are covered with either asphalt or gravel. Site groundwater is not currently used, and due to the brackish nature of the groundwater, future potable use is not anticipated.

### **3.0 APPLICABLE EXPOSURE FORMULAS**

The exposure formulas incorporated in ARES are based on the formulas given in RAGS, Human Health Evaluation Manual, Part A (EPA, 1989b) and Part B (EPA, 1991a). Identifiers have been added to the basic exposure factor abbreviations to differentiate those factors that are used in multiple formulas. The following formulas are used in the ARES for QADSY:

### 3.1 Indoor Air, Inhalation Exposure

$$\text{Intake (mg/kg/day)} = \frac{CAi * IRa * EF * ED}{BW * AT}$$

Where:

- CAi = chemical concentration in indoor air (mg/m<sup>3</sup>).
- IRa = intake rate for indoor air (m<sup>3</sup>/day).
- EF = exposure frequency (days/year).
- ED = exposure duration (years).
- BW = body weight (kg).
- AT = period of time over which exposure is averaged (days).

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### 3.2 Soil, Dermal Exposure

$$\text{Intake (mg/kg/day)} = \frac{CS * FC * SA * AF * ABS * EF * ED}{BW * AT}$$

Where:

- CS = chemical concentration in soil (mg/kg).
- FC = conversion factor for soil (kg/mg).
- SA = skin surface area available for soil contact (cm<sup>2</sup>/event).
- AF = soil to skin adherence factor (mg/cm<sup>2</sup>).
- ABS = chemical-specific absorption factor (unitless).
- EF = exposure frequency (events/year).
- ED = exposure duration (years).
- BW = body weight (kg).
- AT = period of time over which exposure is averaged (days).

EPA is currently developing a new methodology using a soil permeability coefficient in place of ABS. However, according to EPA (1992), "...since these procedures are not as well developed, it is currently recommended that the users first consider the ABS procedures for estimating dose."

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### 3.3 Soil, Oral Exposure

For adult and child exposures:

$$\text{Intake (mg/kg/day)} = \frac{CS * IRs * FC * FI * EF * ED}{BW * AT}$$

Where:

CS = chemical concentration in soil (mg/kg).  
 IRs = soil ingestion rate (mg/day).  
 FC = conversion factor for soil/sediment (kg/mg).  
 FI = fraction of soil ingested from contaminated source (unitless).  
 EF = exposure frequency for soil (days/year).  
 ED = exposure duration (years).  
 BW = body weight (kg).  
 AT = averaging time (days).

For lifetime exposure (derived from EPA, 1991b; Incidental Ingestion of Soil and Dust):

$$\text{Intake (mg/kg/day)} = Y_c * \sum_{i=1}^2 \frac{IRs_i * ED_i}{BW_i}$$

Where:

$Y_c = CS * FC * FI * EF / AT$ .  
 $IRs_i$  = soil ingestion rate (mg/day; age-dependent; EPA, 1991b).  
 $ED_i$  = exposure duration (years; age range for particular ingestion rate; EPA, 1991b).  
 $BW_i$  = body weight (kg; age-dependent; EPA, 1989a).

<u>i</u>	<u>IRs</u>	<u>ED</u>	<u>BW</u>
1	200	6	15
2	100	24	70

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## 4.0 EXPOSURE PARAMETERS

### 4.1 ABS

All values are recommended by EPA Region III (Jafolla, 1995) with the exception of chromium VI.

Arsenic	0.032	Wester <i>et al.</i> , 1993
Chromium VI	0.15	Hawley, 1985

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Inorganic chemicals (not otherwise specified)	0.01	Ryan <i>et al.</i> , 1987
Semivolatile organic chemicals	0.10	Ryan <i>et al.</i> , 1987
Volatile organic chemicals	0.25	Ryan <i>et al.</i> , 1987

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#### 4.2 AF

1.00 mg/cm <sup>2</sup>	Median of the absorption values (0.5 to 1.5 mg/cm <sup>2</sup> ) produced by Lepow <i>et al.</i> (1975) and Roels <i>et al.</i> (1980) and reported in EPA, 1984. This value is also provided as an upperbound estimate by EPA (1992).
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#### 4.3 AT

Carcinogenic effects	70 years * 365 days/year	EPA, 1989b
Noncarcinogenic effects	ED (years) * 365 days/year	EPA, 1989b

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#### 4.4 BW

##### Adult Residential / Adult Worker

70 kg	Average (male and female) of 50th percentile values for age = 18 to 75 years. For lifetime residential soil ingestion, see Section 3.3 of this documentation.	EPA, 1985
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##### Child Residential

15 kg	Average (male and female) of 50th percentile values for age = 1 to 6 years.	EPA, 1985
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##### Lifetime Residential

59 kg	Assumes a child body weight of 15 kg for 6 years and an adult body weight of 70 kg for 24 years.
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$$\frac{(15 \text{ kg} * 6 \text{ years}) + (70 \text{ kg} * 24 \text{ years})}{30 \text{ years}} = 59 \text{ kg}$$


---



#### 4.5 CA

The concentrations of chemicals in indoor air that have volatilized from onsite groundwater are modeled values based on chemical-specific parameters (i.e., groundwater concentration, Henry's Law constant,  $K_{ow}$ , etc.) and site-specific parameters (i.e., depth to groundwater, soil porosity, etc.). A detailed description of the methodology used to model indoor air exposure concentrations from groundwater is presented in Section 6.2.3.3 of the HRA. A listing of the groundwater data points used in the exposure concentration calculation is presented in Appendix J, Table J-4.

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#### 4.6 CS

The upper 95 percent confidence limit ( $UCL_{95}$ ) of the mean chemical concentration was used to represent the RME exposure concentration. If the  $UCL_{95}$  exceeded the maximum detected chemical concentration, the maximum concentration was used to represent the RME. A description of the dataset used to model soil exposure concentrations is presented in Section 6.2.3.3 of the HRA. A listing of the soil data points used in the exposure concentration calculation is presented in Appendix J, Table J-3.

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#### 4.7 ED

##### Adult Residential / Lifetime Residential

30 years

National 90th percentile time at one residence

EPA, 1989b

For lifetime ingestion of soil, see Section 3.3 of this documentation.

---

##### Adult Worker

25 years

National 95th percentile time at one workplace

EPA, 1991b

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##### Child Residential

6 years

Assumes exposure for children age = 1 to 6 years, inclusive, in rural/residential areas

**4.8 EF**Adult Residential / Child Residential / Lifetime Residential

350 days/year

Amount of time spent at home

EPA, 1991b

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Adult Worker (Current)

50 days/year

Conservative assumed value for a worker who visits the  
equipment storage shed one time per week

-----

Adult Worker (Future)

250 days/year

Number of days spent at work

EPA, 1991b

**4.9 FC** $1 \times 10^{-6}$  kg/mg

EPA, 1989b

**4.10 FI**

1.00

Assumes that all ingested soil is from contaminated source.

**4.11 IRa**Adult Residential15 m<sup>3</sup>/dayReasonable conservative inhalation  
rate for indoor residential exposure

EPA, 1991b

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Adult Worker (Current)4 m<sup>3</sup>/dayModerate inhalation rate (2 m<sup>3</sup>/hour) multiplied by the  
assumed time spent working near the area (2 hours/day) (EPA,  
1989a)

-----

Adult Worker (Future)20 m<sup>3</sup>/dayReasonable upper-bound occupational  
inhalation rate for an 8-hour workday

EPA, 1991b

Child Residential16 m<sup>3</sup>/dayReasonable conservative inhalation rate for child based on  
indoor activity patterns and inhalation rates for a 6-year old  
child (EPA, 1989a)Lifetime Residential15.2 m<sup>3</sup>/dayAssumes a child inhalation of 16 m<sup>3</sup>/day for 6 years and an  
adult inhalation of 15 m<sup>3</sup>/day for 24 years

$$\frac{(16 \text{ m}^3/\text{day} * 6 \text{ years}) + (15 \text{ m}^3/\text{day} * 24 \text{ years})}{30 \text{ years}} = 15.2 \text{ m}^3/\text{day}$$

## 4.12 IRs

Adult Residential

100 mg/day

EPA, 1991b

Adult Worker (Current)

12.5 mg/day

Conservative value based on the  
interim default value for adult soil  
ingestion during an 8-hour workday  
(50 mg/day) and assumes that a worker  
may spend 2 hours/day in the area

The actual rate of soil ingestion for a worker at the maintenance building is expected  
to be lower as the area in the vicinity of the building is paved.

Adult Worker (Future)

50 mg/day

EPA, 1991b

Child Residential

200 mg/day

EPA, 1991b

Lifetime Residential

Soil ingestion rates are age-dependent. For an explanation of these intake rates, see Section 3.3 of this documentation.

## 4.13 SA

All adult surface area values are mean values from EPA, 1992. All child surface area values are 50<sup>th</sup> percentile values from EPA, 1985. Mean and 50<sup>th</sup> percentile values are used because surface area is related to body weight, and average body weights over the ED were used in the exposure calculations. Adult values are based on average adult (male and female) body part surface areas (m<sup>2</sup>) multiplied by a conversion factor of 10,000 cm<sup>2</sup>/m<sup>2</sup> and rounded to three significant figures. Child values were calculated using the average (male and female) mean percentage of total body surface area by part (m<sup>2</sup>) over the age range multiplied by the average (male and female) 50<sup>th</sup> percentile total body surface area over that age range. The final values were multiplied by a conversion factor of 10,000 cm<sup>2</sup>/m<sup>2</sup> and rounded to three significant figures.

Adult ResidentialFully clothed

hands	793.
head	<u>1,140.</u>
	1,933. cm <sup>2</sup>

Partially clothed

hands	793.
arms	2,190.
feet	1,048.
lower legs	2,005.
head	<u>1,140.</u>
	7,176. cm <sup>2</sup>

Based on 1) 108 days/year partially clothed [assumed to apply 5 days/week when maximum daily air temperature exceeds 75°F (5/7 \* 151 = 108 days/year)], 2) remainder of days without ground snow cover spent fully clothed (365 - 108 - 2 = 255 days/year), and 3) no exposure on days with ground snow cover.

$$\frac{(108 \text{ days/year} * 7,176 \text{ cm}^2) + (255 \text{ days/year} * 1,933 \text{ cm}^2)}{365 \text{ days/year}} \approx 3,470 \text{ cm}^2$$

Percentage of days with maximum temperatures above 75°F is based on climatological data collected at Norfolk Naval Air Station, Norfolk, VA for 1945 through 1990 (NOAA, 1992) and is presented in Table K-1.

Adult Worker

hands	793.
forearms	1,095.
head	<u>1,140.</u>
	3,028. cm <sup>2</sup> $\approx$ 3,030 cm <sup>2</sup>

It is assumed that workers at the site will wear long pants but may have exposed arms while cutting grass at the facility.

### Child Residential

#### Fully clothed

hands	391.
head	<u>1,000.</u>
	1,391. cm <sup>2</sup>

#### Partially clothed

hands	391.
arms	915.
feet	479.
legs	1,735.
head	<u>1,000.</u>
	4,520. cm <sup>2</sup>

Based on 1) 108 days/year partially clothed [assumed to apply 5 days/week when maximum daily air temperature exceeds 75°F ( $5/7 * 151 = 108$  days/year)], 2) remainder of days without ground snow cover spent fully clothed ( $365 - 108 - 2 = 255$  days/year), and 3) no exposure on days with ground snow cover.

$$\frac{(108 \text{ days/year} * 4,520 \text{ cm}^2) + (255 \text{ days/year} * 1,391 \text{ cm}^2)}{365 \text{ days/year}} \approx 2,310 \text{ cm}^2$$

Percentage of days with maximum temperatures above 75°F is based on climatological data collected at Norfolk Naval Air Station, Norfolk, VA for 1945 through 1990 (NOAA, 1992) and is presented in Table K-1.

### Lifetime Residential

3,241 cm<sup>2</sup>

Assumes a child surface area of 2,310 cm<sup>2</sup> for 6 years and an adult surface area of 3,470 cm<sup>2</sup> for 24 years

$$\frac{(2,310 \text{ cm}^2 * 6 \text{ years}) + (3,470 \text{ cm}^2 * 24 \text{ years})}{30 \text{ years}} \approx 3,240 \text{ cm}^2$$

Table K-1. Meteorological Data for Norfolk Naval Air Station

## -----INTERNATIONAL STATION METEOROLOGICAL CLIMATE SUMMARY-----

:STA 723085 | KNGU | NORFOLK NAS ,VA,US  
 :LAT 36 56N :LONG 076 17W :ELEV 16(ft) 5(m) :TYPE NAVY SMOS V2.1 02071992  
 37 - STATION CLIMATIC SUMMARY

POR: (HOURLY): 1945-1990

TEMPERATURE (DEG F)					PRECIPITATION (INCHES) (^)					REL HUM VAP DEW PR					WIND (KTS)					MEAN NO. OF DAYS WITH (&)												TEMP (DEG F)				
MEANS		EXTREME			PRECIP.			SNOWFALL (@)		PERCENT		PR	PT.	ALT	SKY			PRECIP.	SNOW-							TH	FOG	MAX	MAX	MIN	MIN					
							24H		24H	(LST)	IN.	(F)	FT.	PREVAIL	MAX	CVR	INCHES	FALL (")	TH	FOG	MAX	MAX	MIN	MIN												
MAX	MIN	AVG	MAX	MIN	MEAN	MAX	MIN	MAX	MEAN	MAX	MAX	AM	PM	HG.		\$	DIR	SPD	GST	+	>=	>=	>=	>=	STM	*	>=	>=	<=	<=						
												07	16																							
JAN	48	34	41	78	-1	3.2	8.9	.9	2.5	2	12	7	71	59	.16	29	60	NNE	11	55	OVR	10	2	1	1	#	13	0	#	14	1					
FEB	50	35	43	82	12	3.2	6.3	.6	2.7	3	25	13	71	57	.17	30	70	NNE	12	58	OVR	10	2	1	#	1	12	0	1	11	#					
MAR	58	41	50	90	20	3.2	9.1	.4	2.4	1	19	11	73	55	.22	36	65	SSW	11	59	OVR	10	2	#	#	2	12	#	3	4	0					
APR	67	50	59	93	29	2.8	6.7	.5	2.7	T	T	T	71	52	.29	44	65	SSW	10	61	OVR	10	2	#	0	3	11	#	8	#	0					
MAY	76	59	68	97	37	3.3	9.3	.6	2.8	0	0	0	75	57	.43	55	45	SSW	9	59	OVR	10	2	0	0	5	14	2	17	0	0					
JUN	83	67	76	101	47	3.3	9.6	.4	5.2	0	0	0	77	58	.59	64	40	SSW	9	61	SCT	9	2	0	0	6	12	7	26	0	0					
JUL	87	72	80	100	58	4.5	12.2	1.0	6.5	0	0	0	80	61	.71	69	30	SSW	9	65	SCT	11	3	0	0	8	12	11	31	0	0					
AUG	85	72	79	102	52	4.4	11.8	.9	6.4	0	0	0	82	63	.70	68	25	SSW	8	70	SCT	10	3	0	0	7	15	9	30	0	0					
SEP	80	67	74	100	50	3.9	18.2	.5	7.9	0	0	0	80	62	.57	63	35	ENE	9	66	SCT	7	2	0	0	3	13	3	23	0	0					
OCT	70	56	63	93	33	2.7	9.5	.2	3.3	0	0	0	78	60	.39	52	45	NNE	12	85	OVR	7	2	0	0	1	14	#	9	0	0					
NOV	61	46	54	84	21	2.7	6.3	.4	2.8	T	2	1	75	58	.26	42	55	SSW	9	63	OVR	8	2	#	0	1	13	0	3	2	0					
DEC	52	37	45	79	9	2.9	6.6	.5	2.6	1	16	9	72	59	.19	33	60	SSW	9	61	OVR	9	2	#	#	13	0	#	10	#						
ANN	68	53	61	102	-1	40.2	67.8	21.8	7.9	7	45	13	75	58	.35	49	55	SSW	10	85	OVR	111	26	2	1	37	154	32	151	40	1					
POR	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	44	46	46	43	44	46	46	46	46	38	38	46	46	46	46					

T = TRACE AMOUNTS ( < .05 < .5 INCHES

# = MEAN NO. DAYS < .5 DAYS

\$ = PRESSURE ALTITUDE IN TENS OF FEET (I.E. 50 = 500 FEET)

@ = NAVY STATIONS REPORT HAIL AS SNOWFALL; ALSO NWS FROM JULY,1948 - DEC.,1955

+ = THE PREDOMINANT SKY CONDITION\PRECIP > LISTED AMOUNT AND < NEXT WHOLE INCH

\* = VISIBILITY IS NOT CONSIDERED

& = ANN TOTALS MAY NOT EQUAL SUM OF MONTHLY VALUES DUE TO ROUNDING

^ = 24 HR MAX PRECIP AND SNOWFALL ARE DAILY TOTALS (MID-NIGHT TO MID-NIGHT)

I = EXCESSIVE MISSING DATA - VALUE NOT COMPUTED

" = INCHES

-----FEDERAL CLIMATE COMPLEX ASHEVILLE-----

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**Appendix L**  
**Intake Values**

QDRUM ARES -- CURRENT WORKER SCENARIO  
Carcinogenic Intakes and Risks

14:28 Tuesday, May 7, 1996 1

CONTAREA  
=====

RECEPTOR	CURR/FUT	MEDIUM	PATHWAY	CHEMNAME	INTAKE	ORALWOE	INHWOE	RMERISK
=====	=====	=====	=====	=====	=====	=====	=====	=====
ADWRK	CURR	IA	INH	Vinyl chloride	5.84E-05	A	A	1.75E-05
			INH	Dichloroethene, 1,1-	8.14E-05	C	C	1.46E-05
			INH	Carbon tetrachloride	3.33E-05	B2	B2	1.75E-06
			INH	Trichloroethene	1.85E-04	B2	B2	1.11E-06
			INH	Chloroform	2.65E-06	B2	B2	2.15E-07
			INH	Tetrachloroethene	5.26E-05	B2	B2	1.05E-07
			INH	Methylene chloride	3.33E-07	B2	B2	5.32E-10
			INH	Dichloroethane, 1,1-	3.94E-05	C	C	
INH	Bromodichloromethane	3.24E-06	B2	B2				
ADWRK	CURR	SO	DERM	Nitrosodi-N-propylamine, N-	5.10E-07	B2	B2	3.57E-06
			ORAL	Nitrosodi-N-propylamine, N-	2.10E-08	B2	B2	1.47E-07
			DERM	Benzo(a)pyrene	1.80E-08	B2	B2	1.31E-07
			DERM	Dinitrotoluene, 2,4-	1.05E-07	B2	B2	7.14E-08
			DERM	Benz(a)anthracene	2.82E-08	B2	B2	2.06E-08
			DERM	Benzo(b)fluoranthene	2.75E-08	B2	B2	2.01E-08
			DERM	Indeno(1,2,3-cd)pyrene	1.76E-08	B2	B2	1.28E-08
			ORAL	Benzo(a)pyrene	7.43E-10	B2	B2	5.42E-09
			DERM	Aldrin	2.96E-10	B2	B2	5.04E-09
			DERM	Chlordane, gamma-	2.47E-09	B2	B2	3.20E-09
			ORAL	Dinitrotoluene, 2,4-	4.33E-09	B2	B2	2.95E-09
			DERM	Chlordane, alpha-	2.02E-09	B2	B2	2.62E-09
			DERM	Benzo(k)fluoranthene	1.29E-08	B2	B2	9.43E-10
			ORAL	Benz(a)anthracene	1.16E-09	B2	B2	8.49E-10
			ORAL	Benzo(b)fluoranthene	1.14E-09	B2	B2	8.29E-10
			ORAL	Indeno(1,2,3-cd)pyrene	7.25E-10	B2	B2	5.29E-10
			DERM	BHC, gamma- (Lindane)	2.33E-10	B2/C	B2/C	3.03E-10
			DERM	Chrysene	2.86E-08	B2	B2	2.09E-10
			ORAL	Aldrin	1.22E-11	B2	B2	2.08E-10
			ORAL	Chlordane, gamma-	1.02E-10	B2	B2	1.32E-10
			ORAL	Chlordane, alpha-	8.33E-11	B2	B2	1.08E-10
			ORAL	Benzo(k)fluoranthene	5.33E-10	B2	B2	3.89E-11
			ORAL	BHC, gamma- (Lindane)	9.61E-12	B2/C	B2/C	1.25E-11
			ORAL	Chrysene	1.18E-09	B2	B2	8.61E-12

QDRUM ARES -- FUTURE WORKER SCENARIO  
Carcinogenic Intakes and Risks

14:33 Tuesday, May 7, 1996 1

CONTAREA =====	RECEPTOR =====	CURR/FUT =====	MEDIUM =====	PATHWAY =====	CHEMNAME =====	INTAKE =====	ORALWOE =====	INHWOE =====	RMERISK =====
1	ADWRK	CURR	IA	INH	Vinyl chloride	1.46E-03	A	A	4.38E-0
				INH	Dichloroethene, 1,1-	2.03E-03	C	C	3.66E-04
				INH	Carbon tetrachloride	8.32E-04	B2	B2	4.37E-05
				INH	Trichloroethene	4.63E-03	B2	B2	2.78E-05
				INH	Chloroform	6.63E-05	B2	B2	5.37E-06
				INH	Tetrachloroethene	1.31E-03	B2	B2	2.63E-06
				INH	Methylene chloride	8.32E-06	B2	B2	1.33E-08
				INH	Dichloroethane, 1,1-	9.85E-04	C	C	
				INH	Bromodichloromethane	8.11E-05	B2	B2	
1	ADWRK	CURR	SO	DERM	Nitrosodi-N-propylamine, N-	2.55E-06	B2	B2	1.78E-05
				ORAL	Nitrosodi-N-propylamine, N-	4.20E-07	B2	B2	2.94E-06
				DERM	Benzo(a)pyrene	9.00E-08	B2	B2	6.57E-07
				DERM	Dinitrotoluene, 2,4-	5.25E-07	B2	B2	3.57E-07
				ORAL	Benzo(a)pyrene	1.49E-08	B2	B2	1.08E-07
				DERM	Benzo(a)anthracene	1.41E-07	B2	B2	1.03E-07
				DERM	Benzo(b)fluoranthene	1.38E-07	B2	B2	1.00E-07
				DERM	Indeno(1,2,3-cd)pyrene	8.79E-08	B2	B2	6.42E-08
				ORAL	Dinitrotoluene, 2,4-	8.67E-08	B2	B2	5.89E-08
				DERM	Aldrin	1.48E-09	B2	B2	2.52E-08
				ORAL	Benzo(a)anthracene	2.33E-08	B2	B2	1.70E-08
				ORAL	Benzo(b)fluoranthene	2.27E-08	B2	B2	1.66E-08
				DERM	Chlordane, gamma-	1.23E-08	B2	B2	1.60E-08
				DERM	Chlordane, alpha-	1.01E-08	B2	B2	1.31E-08
				ORAL	Indeno(1,2,3-cd)pyrene	1.45E-08	B2	B2	1.06E-08
				DERM	Benzo(k)fluoranthene	6.46E-08	B2	B2	4.72E-09
				ORAL	Aldrin	2.45E-10	B2	B2	4.16E-09
				ORAL	Chlordane, gamma-	2.03E-09	B2	B2	2.64E-09
				ORAL	Chlordane, alpha-	1.67E-09	B2	B2	2.16E-09
				DERM	BHC, gamma- (Lindane)	1.16E-09	B2/C	B2/C	1.51E-09
				DERM	Chrysene	1.43E-07	B2	B2	1.04E-09
				ORAL	Benzo(k)fluoranthene	1.07E-08	B2	B2	7.78E-10
				ORAL	BHC, gamma- (Lindane)	1.92E-10	B2/C	B2/C	2.50E-10
				ORAL	Chrysene	2.36E-08	B2	B2	1.72E-10

QDRUM ARES -- FUTURE RESIDENTIAL SCENARIO  
Carcinogenic Intakes and Risks

14:30 Tuesday, May 7, 1996 1

CONTAREA  
=====

RECEPTOR =====	CURR/FUT =====	MEDIUM =====	PATHWAY =====	CHEMNAME =====	INTAKE =====	ORALWOE =====	INHWOE =====	RMERISK =====
LIFRES	FUT	IA	INH	Vinyl chloride	2.21E-03	A	A	6.64E-04
			INH	Dichloroethene, 1,1-	3.08E-03	C	C	5.55E-04
			INH	Carbon tetrachloride	1.26E-03	B2	B2	6.61E-05
			INH	Trichloroethene	7.02E-03	B2	B2	4.21E-05
			INH	Chloroform	1.00E-04	B2	B2	8.13E-06
			INH	Tetrachloroethene	1.99E-03	B2	B2	3.98E-06
			INH	Methylene chloride	1.26E-05	B2	B2	2.02E-08
			INH	Dichloroethane, 1,1-	1.49E-03	C	C	
			INH	Bromodichloromethane	1.23E-04	B2	B2	
LIFRES	FUT	SO	DERM	Nitrosodi-N-propylamine, N-	5.43E-06	B2	B2	3.80E-05
			ORAL	Nitrosodi-N-propylamine, N-	3.77E-06	B2	B2	2.64E-05
			DERM	Benzo(a)pyrene	1.92E-07	B2	B2	1.40E-06
			ORAL	Benzo(a)pyrene	1.33E-07	B2	B2	9.71E-07
			DERM	Dinitrotoluene, 2,4-	1.12E-06	B2	B2	7.61E-07
			ORAL	Dinitrotoluene, 2,4-	7.77E-07	B2	B2	5.28E-07
			DERM	Benzo(a)anthracene	3.01E-07	B2	B2	2.19E-07
			DERM	Benzo(b)fluoranthene	2.93E-07	B2	B2	2.14E-07
			ORAL	Benzo(a)anthracene	2.09E-07	B2	B2	1.52E-07
			ORAL	Benzo(b)fluoranthene	2.04E-07	B2	B2	1.49E-07
			DERM	Indeno(1,2,3-cd)pyrene	1.87E-07	B2	B2	1.37E-07
			ORAL	Indeno(1,2,3-cd)pyrene	1.30E-07	B2	B2	9.49E-08
			DERM	Aldrin	3.16E-09	B2	B2	5.37E-08
			ORAL	Aldrin	2.19E-09	B2	B2	3.73E-08
			DERM	Chlordane, gamma-	2.63E-08	B2	B2	3.42E-08
			DERM	Chlordane, alpha-	2.15E-08	B2	B2	2.80E-08
			ORAL	Chlordane, gamma-	1.82E-08	B2	B2	2.37E-08
			ORAL	Chlordane, alpha-	1.49E-08	B2	B2	1.94E-08
			DERM	Benzo(k)fluoranthene	1.38E-07	B2	B2	1.00E-08
			ORAL	Benzo(k)fluoranthene	9.55E-08	B2	B2	6.97E-09
			DERM	BHC, gamma- (Lindane)	2.48E-09	B2/C	B2/C	3.23E-09
			ORAL	BHC, gamma- (Lindane)	1.72E-09	B2/C	B2/C	2.24E-09
			DERM	Chrysene	3.05E-07	B2	B2	2.22E-09
			ORAL	Chrysene	2.11E-07	B2	B2	1.54E-09

QDRUM ARES--CURRENT WORKER  
Noncarcinogenic Intakes and Hazard Indices

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CONTAREA =====	RECEPTOR =====	CURR/FUT =====	MEDIUM =====	PATHWAY =====	CHEMNAME =====	INTAKE =====	RMEHI =====
1	ADWRK	CURR	IA	INH	Carbon tetrachloride	9.32E-05	1.63E-01
				INH	Trichloroethane, 1,1,1-	6.46E-04	2.23E-03
				INH	Dichloroethane, 1,1-	1.10E-04	7.88E-04
				INH	Methylene chloride	9.32E-07	1.08E-06
				INH	Dichloroethene, 1,1-	2.28E-04	
				INH	Dichloroethenes, 1,2-, total	1.68E-04	
				INH	Acetone	1.64E-06	
				INH	Bromodichloromethane	9.08E-06	
				INH	Vinyl chloride	1.64E-04	
				INH	Chloroform	7.42E-06	
				INH	Tetrachloroethene	1.47E-04	
				INH	Trichloroethene	5.19E-04	
1	ADWRK	CURR	SO	DERM	Thallium	7.43E-07	9.28E-03
				ORAL	Thallium	3.06E-07	3.83E-03
				DERM	Nitrosodi-N-propylamine, N-	1.43E-06	1.50E-04
				DERM	Dinitrotoluene, 2,4-	2.94E-07	1.47E-04
				DERM	Chlordane, gamma-	6.90E-09	1.15E-04
				DERM	Chlordane, alpha-	5.65E-09	9.42E-05
				DERM	Aldrin	8.30E-10	2.77E-05
				ORAL	Nitrosodi-N-propylamine, N-	5.89E-08	6.20E-06
				ORAL	Dinitrotoluene, 2,4-	1.21E-08	6.07E-06
				ORAL	Chlordane, gamma-	2.85E-10	4.75E-06
				ORAL	Chlordane, alpha-	2.33E-10	3.89E-06
				DERM	Chrysene	8.00E-08	2.67E-06
				DERM	Benz(a)anthracene	7.90E-08	2.63E-06
				DERM	Benzo(b)fluoranthene	7.71E-08	2.57E-06
				DERM	BHC, gamma- (Lindane)	6.52E-10	2.17E-06
				DERM	Benzo(a)pyrene	5.04E-08	1.68E-06
				DERM	Indeno(1,2,3-cd)pyrene	4.92E-08	1.64E-06
				DERM	Benzo(k)fluoranthene	3.62E-08	1.21E-06
				ORAL	Aldrin	3.42E-11	1.14E-06
				ORAL	Chrysene	3.30E-09	1.10E-07
				ORAL	Benz(a)anthracene	3.26E-09	1.09E-07
				ORAL	Benzo(b)fluoranthene	3.18E-09	1.06E-07
				ORAL	BHC, gamma- (Lindane)	2.69E-11	8.97E-08
				ORAL	Benzo(a)pyrene	2.08E-09	6.93E-08
				ORAL	Indeno(1,2,3-cd)pyrene	2.03E-09	6.77E-08
				ORAL	Benzo(k)fluoranthene	1.49E-09	4.97E-08

QDRUM ARES--FUTURE WORKER  
Noncarcinogenic Intakes and Hazard Indices

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CONTAREA  
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RECEPTOR =====	CURR/FUT =====	MEDIUM =====	PATHWAY =====	CHEMNAME =====	INTAKE =====	RMEHI =====
ADWRK	CURR	IA	INH	Carbon tetrachloride	2.33E-03	4.09E+00
			INH	Trichloroethane, 1,1,1-	1.61E-02	5.57E-02
			INH	Dichloroethane, 1,1-	2.76E-03	1.97E-02
			INH	Methylene chloride	2.33E-05	2.71E-05
			INH	Dichloroethene, 1,1-	5.69E-03	
			INH	Dichloroethenes, 1,2-, total	4.21E-03	
			INH	Acetone	4.09E-05	
			INH	Bromodichloromethane	2.27E-04	
			INH	Vinyl chloride	4.09E-03	
			INH	Chloroform	1.86E-04	
			INH	Tetrachloroethene	3.68E-03	
			INH	Trichloroethene	1.30E-02	
ADWRK	CURR	SO	ORAL	Thallium	6.13E-06	7.66E-02
			DERM	Thallium	3.71E-06	4.64E-02
			DERM	Nitrosodi-N-propylamine, N-	7.14E-06	7.51E-04
			DERM	Dinitrotoluene, 2,4-	1.47E-06	7.35E-04
			DERM	Chlordane, gamma-	3.45E-08	5.75E-04
			DERM	Chlordane, alpha-	2.83E-08	4.71E-04
			DERM	Aldrin	4.15E-09	1.38E-04
			ORAL	Nitrosodi-N-propylamine, N-	1.18E-06	1.24E-04
			ORAL	Dinitrotoluene, 2,4-	2.43E-07	1.21E-04
			ORAL	Chlordane, gamma-	5.69E-09	9.49E-05
			ORAL	Chlordane, alpha-	4.66E-09	7.77E-05
			ORAL	Aldrin	6.85E-10	2.28E-05
			DERM	Chrysene	4.00E-07	1.33E-05
			DERM	Benz(a)anthracene	3.95E-07	1.32E-05
			DERM	Benzo(b)fluoranthene	3.85E-07	1.28E-05
			DERM	BHC, gamma- (Lindane)	3.26E-09	1.09E-05
			DERM	Benzo(a)pyrene	2.52E-07	8.40E-06
			DERM	Indeno(1,2,3-cd)pyrene	2.46E-07	8.20E-06
			DERM	Benzo(k)fluoranthene	1.81E-07	6.03E-06
			ORAL	Chrysene	6.60E-08	2.20E-06
			ORAL	Benz(a)anthracene	6.52E-08	2.17E-06
			ORAL	Benzo(b)fluoranthene	6.36E-08	2.12E-06
			ORAL	BHC, gamma- (Lindane)	5.38E-10	1.79E-06
			ORAL	Benzo(a)pyrene	4.16E-08	1.39E-06
			ORAL	Indeno(1,2,3-cd)pyrene	4.06E-08	1.35E-06
			ORAL	Benzo(k)fluoranthene	2.98E-08	9.95E-07

QDRUM ARES--FUTURE RESIDENTIAL  
Noncarcinogenic Intakes and Hazard Indices

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CONTAREA =====	RECEPTOR =====	CURR/FUT =====	MEDIUM =====	PATHWAY =====	CHEMNAME =====	INTAKE =====	RMEHI =====
1	ADRES	FUT	IA	INH	Carbon tetrachloride	2.45E-03	4.29E+00
				INH	Trichloroethane, 1,1,1-	1.70E-02	5.85E-02
				INH	Dichloroethane, 1,1-	2.90E-03	2.07E-02
				INH	Methylene chloride	2.45E-05	2.84E-05
				INH	Dichloroethene, 1,1-	5.98E-03	
				INH	Dichloroethenes, 1,2-, total	4.42E-03	
				INH	Acetone	4.29E-05	
				INH	Bromodichloromethane	2.38E-04	
				INH	Vinyl chloride	4.29E-03	
				INH	Chloroform	1.95E-04	
				INH	Tetrachloroethene	3.86E-03	
				INH	Trichloroethene	1.36E-02	
1	ADRES	FUT	SO	ORAL	Thallium	1.72E-05	2.14E-01
				DERM	Thallium	5.95E-06	7.44E-02
				DERM	Nitrosodi-N-propylamine, N-	1.14E-05	1.20E-03
				DERM	Dinitrotoluene, 2,4-	2.36E-06	1.18E-03
				DERM	Chlordane, gamma-	5.53E-08	9.22E-04
				DERM	Chlordane, alpha-	4.53E-08	7.55E-04
				ORAL	Nitrosodi-N-propylamine, N-	3.30E-06	3.47E-04
				ORAL	Dinitrotoluene, 2,4-	6.80E-07	3.40E-04
				ORAL	Chlordane, gamma-	1.59E-08	2.66E-04
				DERM	Aldrin	6.65E-09	2.22E-04
				ORAL	Chlordane, alpha-	1.31E-08	2.18E-04
				ORAL	Aldrin	1.92E-09	6.39E-05
				DERM	Chrysene	6.41E-07	2.14E-05
				DERM	Benz(a)anthracene	6.33E-07	2.11E-05
				DERM	Benzo(b)fluoranthene	6.18E-07	2.06E-05
				DERM	BHC, gamma- (Lindane)	5.23E-09	1.74E-05
				DERM	Benzo(a)pyrene	4.04E-07	1.35E-05
				DERM	Indeno(1,2,3-cd)pyrene	3.95E-07	1.32E-05
				DERM	Benzo(k)fluoranthene	2.90E-07	9.67E-06
				ORAL	Chrysene	1.85E-07	6.16E-06
				ORAL	Benz(a)anthracene	1.82E-07	6.08E-06
				ORAL	Benzo(b)fluoranthene	1.78E-07	5.94E-06
				ORAL	BHC, gamma- (Lindane)	1.51E-09	5.02E-06
				ORAL	Benzo(a)pyrene	1.16E-07	3.88E-06
				ORAL	Indeno(1,2,3-cd)pyrene	1.14E-07	3.79E-06
				ORAL	Benzo(k)fluoranthene	8.36E-08	2.79E-06
1	CHRES	FUT	IA	INH	Carbon tetrachloride	1.22E-02	2.14E+01
				INH	Trichloroethane, 1,1,1-	8.44E-02	2.91E-01
				INH	Dichloroethane, 1,1-	1.44E-02	1.03E-01
				INH	Methylene chloride	1.22E-04	1.42E-04
				INH	Dichloroethene, 1,1-	2.98E-02	
				INH	Dichloroethenes, 1,2-, total	2.20E-02	
				INH	Acetone	2.14E-04	
				INH	Bromodichloromethane	1.19E-03	
				INH	Vinyl chloride	2.14E-02	
				INH	Chloroform	9.70E-04	
				INH	Tetrachloroethene	1.92E-02	
				INH	Trichloroethene	6.78E-02	

QDRUM ARES--FUTURE RESIDENTIAL  
Noncarcinogenic Intakes and Hazard Indices

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CONTAREA  
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RECEPTOR =====	CURR/FUT =====	MEDIUM =====	PATHWAY =====	CHEMNAME =====	INTAKE =====	RMEHI =====
CHRES	FUT	SO	ORAL	Thallium	1.60E-04	2.00E+00
			DERM	Thallium	1.85E-05	2.31E-01
			DERM	Nitrosodi-N-propylamine, N-	3.55E-05	3.74E-03
			DERM	Dinitrotoluene, 2,4-	7.33E-06	3.66E-03
			ORAL	Nitrosodi-N-propylamine, N-	3.08E-05	3.24E-03
			ORAL	Dinitrotoluene, 2,4-	6.34E-06	3.17E-03
			DERM	Chlordane, gamma-	1.72E-07	2.86E-03
			ORAL	Chlordane, gamma-	1.49E-07	2.48E-03
			DERM	Chlordane, alpha-	1.41E-07	2.35E-03
			ORAL	Chlordane, alpha-	1.22E-07	2.03E-03
			DERM	Aldrin	2.07E-08	6.89E-04
			ORAL	Aldrin	1.79E-08	5.97E-04
			DERM	Chrysene	1.99E-06	6.64E-05
			DERM	Benz(a)anthracene	1.97E-06	6.56E-05
			DERM	Benzo(b)fluoranthene	1.92E-06	6.40E-05
			ORAL	Chrysene	1.73E-06	5.75E-05
			ORAL	Benz(a)anthracene	1.70E-06	5.68E-05
			ORAL	Benzo(b)fluoranthene	1.66E-06	5.54E-05
			DERM	BHC, gamma- (Lindane)	1.62E-08	5.41E-05
			ORAL	BHC, gamma- (Lindane)	1.41E-08	4.69E-05
			DERM	Benzo(a)pyrene	1.26E-06	4.18E-05
			DERM	Indeno(1,2,3-cd)pyrene	1.23E-06	4.09E-05
			ORAL	Benzo(a)pyrene	1.09E-06	3.62E-05
			ORAL	Indeno(1,2,3-cd)pyrene	1.06E-06	3.54E-05
			DERM	Benzo(k)fluoranthene	9.01E-07	3.00E-05
			ORAL	Benzo(k)fluoranthene	7.80E-07	2.60E-05



**Appendix M**  
**Toxicity Profiles**

## CARBON TETRACHLORIDE

(CAS No. 56-23-5)

### INTRODUCTION

Widely used as an industrial solvent, dry cleaning agent, and chemical intermediate, carbon tetrachloride was banned for these purposes by FDA. Currently, it is primarily used in the synthesis of chlorofluoromethanes and as a grain fumigant and pesticide (ORNL, 1989).

Carbon tetrachloride, with a reported water solubility of 780 to 930 mg/L, may be considered soluble (Davies and Dobbs, 1984; Rodgers et al. 1980; Valvani *et al.*, 1980). When considered in conjunction with the high solubility, the moderate soil sorption coefficient ( $K_{oc}$ ) value of 439 (ORNL, 1989) suggests that carbon tetrachloride will be mobile in the soil/groundwater system, although there will be considerable retardation in subsurface or sandy soils. Based on the reported vapor pressure of 90 torr at 20°C (EPA, 1979), transport through the air-filled pores of the near-surface soils may be an important migration pathway. In surficial and near-surface unsaturated soils, an equilibrium partitioning model (ORNL, 1989) indicates that 96 percent of the carbon tetrachloride present will be sorbed to the soil with about 1 percent in the soil-water phase and 3 percent in the soil-air phase. In saturated soils (where soil organic carbon and soil air are negligible), a majority of the carbon tetrachloride (about 65 percent) is still expected to be sorbed to the soil with the balance in the soil-water phase, which can be transported with groundwater.

Because the compound is volatile, the primary fate of carbon tetrachloride is associated with the atmosphere. Photolysis is not an important degradation process in the lower troposphere as photodissociation occurs with light wavelengths shorter than 290 nm, which is found only in the stratosphere above the ozone layer; the estimated tropospheric half-life is 330 years (EPA, 1979). No reaction occurs with hydroxyl radicals, and only in the stratosphere is the compound degraded by the higher energy ultraviolet light to form trichloromethane radicals and chlorine atoms. The former oxidize to phosgene, which is further photodissociated to form more chlorine atoms; the latter are reported to act as catalysts in the destruction of the ozone layer (EPA, 1979). The overall anticipated atmospheric lifetime is 60 to 100 years (EPA, 1984).

Carbon tetrachloride does not undergo rapid hydrolysis under normal environmental conditions; the estimated aqueous hydrolytic half-life for 1,000 mg/L at pH 7 and 25°C is 7 years, and 7,000 years for 1 mg/L (EPA, 1979). Allowing for volatilization, the half-life in a stirred solution is 29 minutes; environmental half-lives are estimated at 1.2 days in a river, 4.8 days from a lake, and 5.8 days from a pond (ORNL, 1989). Microbial degradation is not expected to occur except in treatment systems where the microbes have been acclimatized to the compound (ORNL, 1989). Although carbon tetrachloride is slightly lipophilic and tends to be found at higher concentrations in fatty tissue, no clear evidence of biomagnification exists (EPA, 1979).

## HUMAN HEALTH EFFECTS

### Noncarcinogenic Effects

Chronic and subchronic oral reference doses (RfDs) are available from EPA (IRIS, 1996; EPA, 1995) and are presented in Table 1. No inhalation reference concentrations (RfCs) or RfDs are provided for either chronic or subchronic exposure. EPA provides a chronic oral RfD of 0.0007 mg/kg/day (IRIS, 1992) and an interim subchronic oral RfD of 0.007 mg/kg-bw/day (HEAST, 1992).

The chronic oral and interim subchronic oral RfDs are based on a study by Bruckner *et al.* (1986) in which liver lesions were observed in rats gavaged for 12 weeks at 10 and 33 mg/kg-bw/day (IRIS, 1996). The 10 mg/kg-bw/day (converted to 7.1 mg/kg-bw/day because exposure occurred only 5 days/week) was determined to be the lowest observed adverse effect level (LOAEL), while the lowest dose of 1 mg/kg-bw/day (converted to 0.71 mg/kg-bw/day) was determined to represent the no observed adverse effect level (NOAEL). Applying an uncertainty factor of 100 (10 for animal-to-human extrapolation and 10 for sensitive human subpopulations) results in an interim subchronic oral RfD of 0.0071 mg/kg/day. Applying an additional uncertainty factor of 10 to extrapolate from a subchronic study to chronic exposure results in a chronic oral RfD of 0.00071 mg/kg/day.

Minimal oral chronic or subchronic human exposure data are available, although reports of acute toxicity exist as a result of accidental, medicinal, or suicidal ingestion. The major pathological effects are liver and kidney damage, with death often attributable to acute renal or hepatic failure (Shell, 1990). Complete recovery of renal function from a mild case may take from 100 to 200 days with oliguria reported as the major effect; however, in a more serious poisoning, anuria may occur, leading to hypertension, acidosis, and terminal uremia if renal function is not restored (Goodman and Gilman, 1985). Concurrent CNS symptoms include dizziness, headache, confusion, and delirium (Shell, 1990).

EPA (1984) presents oral data from a carcinogenicity bioassay study involving hamsters in which a gavage dose of 12.26 mg/week for 30 weeks resulted in a 50-percent mortality rate. Because weight gain was depressed following subchronic inhalation exposure to 1 ppm for 90 days, an atmospheric concentration of 1 ppm was established as the LOAEL. At higher doses, liver damage and increased mortality were reported. Chronic human inhalation exposure led to optic nerve damage and degeneration of the myelin sheath of the sciatic nerve. No liver or kidney damage were reported. Animals evidenced hepatomegaly following chronic exposure to atmospheric levels as low as 5 ppm.

### Carcinogenicity

The carcinogenic slope factors (CSFs) and supporting information are summarized in Table 2. EPA (IRIS, 1996) has classified carbon tetrachloride as a group B2 (suspect human) carcinogen via ingestion and inhalation. This classification indicates adequate evidence exists to show carcinogenicity in animals based on carcinogenic responses reported in various animal studies following ingestion and inhalation of carbon tetrachloride (ATSDR, 1989; IRIS, 1996). Isolated observations of liver cancer in humans exposed to carbon tetrachloride have been reported; however, no epidemiological support is available, rendering the human data inadequate (EPA, 1984).

EPA derived an oral cancer slope factor (CSF) of  $0.13 \text{ (mg/kg/day)}^{-1}$  based on the results of several animal studies (IRIS, 1996). Liver cell carcinomas were the major cancer reported in several species, with investigators theorizing that the necrotizing action on the liver was an important factor in carcinogenicity. The oral slope factor determined by EPA from the available data is  $0.13 \text{ (mg/kg/day)}^{-1}$  (IRIS, 1996).

An inhalation unit risk (UR) was calculated assuming a 40 percent absorption rate in humans (EPA, 1984). This absorption coefficient was based on 30 percent absorption in monkeys, and 30 percent and 57 to 65 percent absorption in humans. A range of estimates of UR for inhalation exposures for the four studies cited in IRIS (1996) was determined, with  $1.5 \times 10^{-5} \text{ (}\mu\text{g/m}^3\text{)}^{-1}$  calculated as the geometric mean for the UR. Assuming a healthy 70-kilogram adult inhales  $20 \text{ m}^3/\text{day}$  of air, the inhalation UR may be converted to an inhalation CSF of  $0.053 \text{ (mg/kg/day)}^{-1}$ . The UR (or derived CSF) should not be used if the air concentration exceeds  $700 \text{ }\mu\text{g/m}^3$ , since above this concentration the UR may not be appropriate.

### Mutagenicity

With only one positive mutagenic response elicited in a *Saccharomyces cerevisiae* strain (HSDB, 1996), the available information suggests that this is not a mutagenic compound; insufficient data are available to establish genotoxicity. EPA (IRIS, 1996) reports that no chromosomal or chromatid aberrations were seen in cells exposed to low concentrations, and *in vivo*, unscheduled DNA synthesis assays were negative. Mitotic recombination and gene conversion were reported but only at concentrations that reduced cell viability to 10 percent. EPA (IRIS, 1996) indicates that the possibility remains that carbon tetrachloride may be metabolized to more reactive intermediate compounds that could be mutagenic. Hepatic abnormalities and retarded development were reported at birth in rats exposed *in utero* (HSDB, 1996). Rats given intraperitoneal injections of carbon tetrachloride at 4,800 mg/kg for 10, 15, or 20 days evidenced impairment of spermatogenesis (HSDB, 1996). Decreased sex organ weights and decreased gonadosomatic index were reported in all exposed animals, while increasing cellular damage was reported in the animals exposed for 15 and 20 days (HSDB, 1996).

### **Teratogenicity/Reproductive Effects**

No reproductive data have been identified in the available literature. Based on numerous animal studies, the evidence indicates that embryotoxicity and fetotoxicity occur at levels that are also maternotoxic (ReproText, 1996). No teratogenic effects have been reported at levels known to be fetotoxic or maternotoxic. Reproductively, carbon tetrachloride has been reported to prolong the estrous cycle, cause testicular atrophy, and a diminished sperm count in rats (ReproText, 1996). In rabbits, the only effect reported is limited degeneration of embryonic discs following the *in vivo* exposure of blastocysts to 1.01 mL/kg (Shepard, 1996).

## **ECOTOXICITY**

### **Aquatic Organisms**

Initially, in aquatic systems, levels as low as 35,000  $\mu\text{g/L}$  were judged acutely toxic to fish in bioassays; however, the fact that the tests were static and that this is a very volatile compound suggest that carbon tetrachloride toxicity may have been underestimated and is in fact more toxic (Shell, 1990). Following the exposure of newly hatched fish, the  $\text{LC}_{50}$  at 4 days posthatching was 1,970  $\mu\text{g/L}$  for rainbow trout and 1,640  $\mu\text{g/L}$  for the leopard frog (Shell, 1990). In addition, it has been estimated that concentrations as low as 30  $\mu\text{g/L}$  would adversely affect sensitive aquatic species (Shell, 1990). The lack of adequate data suggests that the  $\text{LC}_{50}$  value reported for the Leopard frog is more appropriate for deriving an acceptable water concentration. Therefore, applying an uncertainty factor of 100 to the reported  $\text{LC}_{50}$  value of 1,640  $\mu\text{g/L}$ , a water TRV of 0.016 mg/L (16  $\mu\text{g/L}$ ) is calculated.

### **Terrestrial Organisms**

No information was available concerning the effects of carbon tetrachloride on vegetation; therefore, there is insufficient information from which to derive a vegetation TRV for either soil or water. In domestic animals, as in the human population, carbon tetrachloride was used as a trematocide in the early 1920s. Acute toxicity was associated with CNS effects. Delayed toxicity effects are related to hepatic and, to a lesser extent, renal damage (Roberson, 1977). While effects were reported in swine exposed to levels of 320 mg/kg-bw, cattle were the most sensitive as an exposure level of 20 mg/kg-bw was reported to be acutely toxic; this represents an acute LOAEL. No information concerning wildlife was found in the available literature.

## **STANDARDS AND CRITERIA**

### **Human Receptors**

A summary of drinking water standards and criteria is presented as Table 3. Due to the ranking of carbon tetrachloride as a Group B2 suspect human carcinogen, EPA has set a nonenforceable Maximum Contaminant Level Goal (MCLG) for drinking water of zero  $\mu\text{g/L}$  (50 FR 46880; 13 Nov 1985) and a Maximum Contaminant Level (MCL) of 5  $\mu\text{g/L}$ , which is enforceable for public water supplies (52 FR 25690; 08 Jul 1987). Also due to its carcinogenic ranking, the EPA

ambient water quality criterion (AWQC) for the protection of human health should be zero  $\mu\text{g/L}$ . However, zero may not be attainable with present technology; therefore, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 4 to 0.04  $\mu\text{g/L}$  for consumption of contaminated drinking water and aquatic organisms (IRIS, 1996). For consumption of aquatic organisms only, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 69.4 to 0.694  $\mu\text{g/L}$ , respectively (IRIS, 1996). These AWQC would yield values for human consumption of water alone (W) of 4.2, 0.42, and 0.042  $\mu\text{g/L}$  for  $10^{-5}$ ,  $10^{-6}$ , and  $10^{-7}$  risks, respectively, based on the following equation:

$$\frac{1}{W + F} = \frac{1}{W} + \frac{1}{F}$$

No national ambient air quality standards (NAAQS) have been developed for carbon tetrachloride under the Clean Air Act (IRIS, 1996). However, the Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure to carbon tetrachloride (ACGIH, 1995). In addition, the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable recommended exposure levels (RELs) and threshold limit values (TLVs), respectively (ACGIH, 1995). These values are presented in the Table 4.

#### **Ecological Receptors**

No AWQCs have been developed for the protection of freshwater or marine organisms. However, chronic and acute lowest observed effect levels (LOELs) have been reported by EPA and are presented in Table 5 (IRIS, 1996).

Table 1. Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects

Chemical	RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/RfD Source	Uncertainty Factors* / (Modifying Factors) <sup>b</sup>
Oral					
Chronic	0.0007	Medium	Liver lesions	IRIS, 1996	1,000 C,H,S
Subchronic	0.007	Medium	Liver lesions	EPA, 1995	100 H,S
Inhalation					
Chronic	--	--	--	--	--
Subchronic	--	--	--	--	--

Note: RfD = reference dose.  
-- = No EPA Review.

\*Uncertainty factors are typically multiples of 10 and are provided using the following codes:

C = to extrapolate from a subchronic study to a chronic endpoint.

H = to extrapolate from an animal study to humans.

S = to protect sensitive human subpopulations.

<sup>b</sup> A modifying factor is an extra safety factor (ranging from 1 to 10) incorporated in the RfD development to account for various other data deficiencies.

Source: ESE.

Table 2. Carcinogenic Slope Factors and Potential Carcinogenic Effects

Chemical	Carcinogenic Slope Factor (CSF) (mg/kg/day) <sup>-1</sup>	Weight-of-Evidence Classification	Type or Site of Cancer	CSF Basis/CSF Source
Oral	0.13	B2	Liver tumors	IRIS, 1996
Inhalation	0.053 <sup>a</sup>	B2	Liver tumors	EPA, 1995

Note: B2 = suspect human carcinogen (adequate evidence of carcinogenicity in animals and insufficient evidence in humans).

<sup>a</sup>Inhalation CSF is based on an inhalation unit risk (UR) of  $1.5 \times 10^{-3} (\mu\text{g}/\text{m}^3)^{-1}$  (IRIS, 1996) and assumes that a healthy 70-kilogram adult inhales 20 m<sup>3</sup> of air per day.

Source: ESE.



Table 3. Human Regulatory Criteria (µg/L)

Compound	SDWA			Drinking Water Health Advisories				AWQC		
	Primary MCL	MCL Goal	Secondary MCL	1-Day*	10-Day*	Longterm*	Lifetime	Fish and Water	Fish Only	Water Only*
Carbon tetrachloride	5	0	--	4,000	160	71	--	0.4°	6.94°	0.42°

Note: SDWA = EPA Safe Drinking Water Act.  
MCL = maximum contaminant level.  
MCLG = maximum contaminant level goal.  
AWQC = EPA ambient water quality criteria.  
-- = no value available.

\*Value is for a 10-kg child.

<sup>b</sup>Value is based on the following formula:

$$\frac{1}{W+F} = \frac{1}{W} + \frac{1}{F}$$

°Carcinogenic; value represents 10<sup>-6</sup> cancer risk.

Source: ESE.

Table 4. Air Quality Standards

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	12.6 c	--	31 c,s
STEL	--	12.6 c (60 min)	63 c,s
CL	200 c (5 min peak in any 4 hours)	--	--

Note:

TWA = time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect.

STEL = short-term exposure limit; 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any time during a workday even if the 8-hour TWA is not exceeded.

CL = ceiling level; unless otherwise specified, the concentration that should not be exceeded at any time during a workday.

c = designates that this chemical is regulated as a potential carcinogen.

s = signifies that dermal absorption may be a significant exposure route for this chemical.

Source: ESE.

Table 5. Ambient Water Quality Criteria

LOEL ( $\mu\text{g/L}$ )	Freshwater	Marine
Acute	35,200	50,000
Chronic	--	--

Source: ESE.

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## CHLOROFORM

(CAS No. 67-66-3)

### INTRODUCTION

Chloroform (trichloromethane) is produced during the chlorination of drinking water and is a common contaminant in potable water supplies. Chloroform was used for several years as an anesthetic but is now used in this capacity only in emergencies and, to some degree, in the tropics, where it is favored over some of the more volatile compounds, such as ether.

Chloroform is a volatile compound (vapor pressure is 151 torr at 20°C) and quickly moves from surface water systems to the atmosphere, where it is attacked by hydroxyl radicals, forming phosgene that is subsequently hydrolyzed to HC, CO<sub>2</sub>, and chlorine oxide radicals that are not likely to persist (EPA, 1980). Half-lives are reported as 1.2 days in a river, 6.2 days in a pond, and 13 days in a lake; the half-life is less than 30 minutes in a stirred aqueous solution (ORNL, 1989).

Volatilization from surficial and near-surface soils is reported to be slower by about one order of magnitude (ORNL, 1989). While airborne chloroform will undergo photooxidation, it does not undergo rapid hydrolysis under normal environmental conditions. Chloroform is not believed to undergo microbial degradation except in acclimated water treatment systems and in active landfills (ORNL, 1989). While chloroform on the soil surface is likely to volatilize, based on the water solubility of 8,200 mg/L at 20°C and the soil sorption coefficient ( $K_{oc}$ ) value of 44, any remaining portion will most likely be leached to groundwater (ORNL, 1989).

### HUMAN HEALTH EFFECTS

#### Noncarcinogenic Effects

Chronic and subchronic oral reference doses (RfDs) are available from EPA (IRIS, 1996; EPA, 1995) and are presented in Table 1. Inhalation reference concentrations (RfCs) are currently under review by an EPA Work Group and no inhalation RfCs or RfDs are provided in IRIS (1996) or HEAST (EPA, 1995).

The chronic oral RfD (and interim subchronic oral RfD) of 0.01 mg/kg/day are based on a chronic animal study by Heywood *et al.* (1979) in which dogs were exposed to chloroform at either 15 or 30 mg/kg/day for 6 days/week for 7.5 years. Fatty cysts and altered hepatocytes, considered to be treatment-related, were observed in livers of some dogs in both treatment groups. Also, a dose-related increase in hepatic enzyme levels was noted in the high-dose animals. Therefore, the LOAEL was determined to be 15 mg/kg/day. Adjusting this value for 7 day/week exposure period and applying an uncertainty factor of 1,000 (10 for use of a LOAEL

instead of a NOAEL, 10 for animal-to-human extrapolation, and 10 for sensitive human subpopulations) results in a chronic oral RfD of 0.01 mg/kg/day.

Chronic oral exposure in humans adversely affects the central nervous system (CNS) as well as the liver, kidneys, and heart (NIOSH, 1974). Chronic effects reported following oral exposure of rats to levels of 60 mg/kg/day or greater include decreased liver weights and serum cholinesterase levels, an increased incidence of a noncancerous respiratory disease, and gonadal atrophy (EPA, 1984). Chloroform readily passes the cell membrane, and effects include CNS disturbances, liver glutathione depletion, and gonadal and bone marrow abnormalities (USATHAMA, 1989). Animals on high-fat or protein-poor diets appear more susceptible to hepatotoxicity, while high-carbohydrate and high-protein diets appear to have a protective effect (USATHAMA, 1989). Liver necrosis and gonad dysfunction were reported in rats at 150 mg/kg/day (Palmer *et al.*, 1979). No effects in humans following subchronic oral exposure at 2.5 mg/kg/day were reported by EPA (1984) or in rats exposed to 30 mg/kg/day (Palmer *et al.*, 1979), but necrosis of the liver and dysfunction of the gonads were reported in rats at 150 mg/kg/day (Palmer *et al.*, 1979).

Occupational human exposure via inhalation in the workplace at levels between 22 and 237 ppm is reported to result in depression, gastrointestinal disturbances, headache, and frequent and scalding urination (EPA, 1984). Other reported effects include cardiac arrhythmia, ventricular tachycardia, and bradycardia. Death from chloroform overdose is attributed to ventricular fibrillation. In rats, inhalation exposure to as little as 25 ppm produced histopathological changes in the liver and kidney (EPA, 1984). Similar effects were present in guinea pigs and rabbits, although the data are questionable as results were observed in the lowest and highest doses, but none were observed at the middle dose.

### Carcinogenicity

Chloroform has been classified as a group B2 (probable human) carcinogen (IRIS, 1996). This classification indicates sufficient evidence of carcinogenicity in animals but inadequate evidence of human carcinogenicity. The carcinogenic slope factors (CSFs) and supporting information are presented in Table 2.

The oral CSF of 0.0061 (mg/kg/day)<sup>-1</sup> was derived from a drinking water bioassay by Jorgenson *et al.* (1985) in which chloroform was administered in drinking water to rats and mice at concentrations of 200, 400, 900, and 1800 mg/L for 104 weeks. These concentrations were reported by the author to correspond to 19, 38, 81, and 160 mg/kg/day for rats and 34, 65, 130, and 263 mg/kg/day for mice. A significant increase in renal tumors in rats was observed in the highest dose group and considered dose-related. The liver tumor incidence in mice was not significantly increased. This study was specifically designed to measure the effects of exposure to low doses of chloroform.

The inhalation unit risk (UR) of  $2.3 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$  is based on a gavage study by NCI (1976) in which mice were dosed with chloroform at time-weighted average levels of 138 and 277 mg/kg/day (males) and 238 and 477 mg/kg/day (females) for 78 weeks. Highly significant increases in hepatocellular carcinomas were observed in mice of both sexes, while hepatic nodular hyperplasia was observed in those animals not developing hepatocellular carcinoma. Mice exposed to 90 mg/kg/day of chloroform developed kidney tumors. Limited data suggest that oral human exposure to chloroform leads to increased risk of bladder, colon, and rectal cancer (EPA, 1984). Assuming that a healthy 70-kg adult inhales 20 m<sup>3</sup> of air per day, an inhalation CSF of  $0.081 (\text{mg}/\text{kg}/\text{day})^{-1}$  is derived (EPA, 1995).

### **Mutagenicity**

Although not independently confirmed, significantly higher frequencies of acquired chromosomal aberrations were noted in the lymphocytes of women occupationally exposed to chloroform and other organic solvents (Funes-Cravioto *et al.*, 1977). Similar findings were observed in the children of these women. The relevance of acquired somatic chromosomal aberrations to the risk of malformations or any other disease in the offspring is unknown.

The majority of tests for genotoxicity of chloroform have been negative (IRIS, 1996). One study, however, demonstrated binding of radiolabeled chloroform to calf thymus DNA following metabolism by rat liver microsomes (IRIS, 1996). Chloroform caused mitotic recombination in *Saccharomyces* (Callen *et al.*, 1980) and sister chromatid exchange in cultured human lymphocytes and in mouse bone marrow cells exposed *in vivo* (Morimoto and Koizumi, 1983). A host-mediated assay using mice indicated that chloroform was metabolized *in vivo* to a form mutagenic to a strain of *Salmonella*. Likewise urine extracts from chloroform-treated mice were mutagenic (Agustin and Lim-Sylianco, 1978).

### **Teratogenicity/Reproductive Effects**

Chloroform crosses the human placenta and can be detected in fetal blood (ReproText, 1996). The frequency of congenital anomalies was no greater than expected among 492 children of laboratory workers occupationally exposed to organic solvents during the first trimester of pregnancy; 128 of these mothers reported first trimester exposure to chloroform (Axelsson *et al.*, 1984). The only cases where chloroform was suspected of human reproductive effects were two cases of eclamptic toxemia of pregnancy in women working in the same laboratory where chloroform was used (ReproText, 1996). Eclampsia in pregnancy follows high blood pressure and retention of fluid and is marked by headache, visual disturbances, and either convulsions, coma, or both.

In general, chloroform has been highly embryotoxic and somewhat teratogenic in animal studies with fetal toxicity generally occurring at exposure levels associated with maternal toxicity



(Shepard, 1996). Teratogenic effects were reported in rats and mice exposed to 30 ppm or higher via inhalation on days 6 to 15 of gestation (EPA, 1984). Following the inhalation of chloroform, rats experienced increased post-implantation deaths, decreased fetal weight gain, reduced conception rate, increased resorptions, and retarded fetal growth (TERIS, 1996). In mice, chloroform impaired pregnancy, increased pre-implantation losses, retarded fetal growth, and caused cleft palates (TERIS, 1996). The frequency of cleft palate was increased among the offspring of mice exposed chronically during pregnancy to chloroform vapors at a concentration 50 times the NIOSH occupational standard of 2 ppm (about 1/100 of the human anesthetic dose) (TERIS, 1996). When male mice were exposed to chloroform through inhalation, structural abnormalities in sperm were reported; this effect was not observed following the intraperitoneal injection of chloroform (ReproText, 1996). Anal atresia was observed with increased frequency among the offspring of pregnant rats after similar exposure, but not after exposure to 15 times the NIOSH occupational standard (TERIS, 1996). In both studies, considerable maternal toxicity occurred.

In contrast, no malformations were observed in the offspring of rats or rabbits given chloroform orally during pregnancy at doses up to 400 mg or 50 mg/kg/day, respectively, although there was evidence of maternal toxicity (ReproText, 1996). Oral doses greater than 100 mg/kg/day in female rabbits were toxic to dam and fetus (USATHAMA, 1989), intimating that 100 mg/kg/day represents a LOAEL for the rabbit (TERIS, 1996).

## **ECOTOXICITY**

### **Aquatic Organisms**

Toxic concentrations reported in the literature for chloroform in aquatic systems cover a wide range of values. Acute toxicity tests conducted on rainbow trout, bluegill, and a daphnia species evidenced median effect concentrations of 28,900 to 115,000  $\mu\text{g/L}$  (EPA, 1980). Birge *et al.* (1980) reported 96-hour  $\text{LC}_{50}$  values of 270 to 35,100  $\mu\text{g/L}$  in toads and frogs exposed from egg stage to hatchlings; fish  $\text{LC}_{50}$  values were reported from 2,030 to 75,000  $\mu\text{g/L}$  (Anderson and Lusty, 1980). Chronic (27-day)  $\text{LC}_{50}$  values of 2,030 and 1,240  $\mu\text{g/L}$  were reported for rainbow trout larvae at water hardness values of 50 and 200 mg/L, respectively (EPA, 1980). The 96-hour  $\text{LC}_{50}$  value of 270  $\mu\text{g/L}$  reported by Birge *et al.* (1980) for toads and frogs may be considered the acute LOAEL. Applying an uncertainty factor of 100 yields a water TRV of 0.0027 mg/L (2.7  $\mu\text{g/L}$ ) for aquatic organisms.

### **Terrestrial Organisms**

No information was identified regarding the toxicity of chloroform to vegetation; however, some general observations may be made regarding potential interactions. With an log octanol-water partition coefficient ( $K_{ow}$ ) of 1.94, chloroform is partially miscible with water based on a regression analysis by Briggs *et al.* (1982, 1983). This suggests that chloroform will enter the

plant and be translocated within the plant structure. As it is lipophilic, it may pass through the cuticle of the leaf, if in contact for a sufficient length of time; conversely, the volatility of the compound would limit the time available.

No oral or inhalant toxic levels are provided for livestock. Booth (1977) states that only a 2 to 4 percent chloroform concentration in air is necessary to induce anesthesia in an animal in a reasonable timeframe of 10 to 12 minutes and that this concentration should be lowered to 1.5 percent for the duration of anesthesia. Dogs fasted for 24 hours and then anesthetized for 1.5 hours evidenced central necrosis of one-third to one-half of the liver lobules. No information regarding the effects in terrestrial wildlife was identified.

## **STANDARDS AND CRITERIA**

### **Human Receptors**

A summary of drinking water standards and criteria is presented as Table 3.

EPA has not established a health-based Maximum Contaminant Level Goal (MCLG) for chloroform in drinking water due to insufficient information (IRIS, 1996). However, an interim MCL of 100  $\mu\text{g/L}$  for total trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) is proposed based on chronic toxicity data for chloroform and existing technology and treatment methods (44 FR 68624). Chloroform produced CNS depression, as well as hepatic, renal, teratogenic and carcinogenic effects at dose levels from 30 to 350 mg/kg. This MCL applies only to community water systems which serve a population of 10,000 or more individuals and add a disinfectant (oxidant) to the water in any part of the drinking water treatment process.

Although inhalation appears to be the primary exposure route for chloroform, EPA concluded that current information does not indicate that chloroform endangers public health at ambient concentrations (excluding emergency releases). Therefore, no regulation directed specifically at chloroform is necessary at this time under the Clean Air Act and no national ambient air quality standards (NAAQS) have been developed for chloroform (IRIS, 1996). EPA indicated that it intends to add chloroform to the list of hazardous air pollutants for which it intends to establish emission standards under section 112(b)(1)(A) of the Clean Air Act. The EPA will decide whether to add chloroform to the list only after studying possible techniques that might be used to control emissions of chloroform and further assessing the public health risks. The EPA will add chloroform to the list if emission standards are warranted.

The Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure (ACGIH, 1995). In addition, the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable recommended

exposure levels (RELs) and threshold limit values (TLVs), respectively (ACGIH, 1995). These values are presented in the following table of air quality criteria.

**Ecological Receptors**

No AWQCs have been developed for the protection of freshwater or marine organisms against exposure to chloroform (IRIS, 1996). However, the LOELs for the freshwater aquatic species tested have been determined (IRIS, 1996). These LOELs, which are established when the minimum data required to derive AWQCs are not available, are presented in the following table.

Table 1. Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects

Chemical	RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/RfD Source	Uncertainty Factors* / (Modifying Factors) <sup>b</sup>
Oral					
Chronic	0.01	Medium	Fatty liver cysts	IRIS, 1996	1,000 H,N,S
Subchronic	0.01	Medium	Fatty liver cysts	EPA, 1995	1,000 H,N,S
Inhalation					
Chronic	--	--	--	--	--
Subchronic	--	--	--	--	--

Note: IRIS = Integrated Risk Information System.  
RfD = reference dose.  
RfC = reference concentration.  
-- = Not available.  
LOAEL = lowest observed adverse effect level.  
NOAEL = no observed adverse effect level.

\*Uncertainty factors are typically multiples of 10 and are provided using the following codes:

H = to extrapolate from an animal study to humans.

N = to extrapolate from a LOAEL to a NOAEL.

S = to protect sensitive human subpopulations.

<sup>b</sup> A modifying factor is an extra safety factor (ranging from 1 to 10) incorporated in the RfD development to account for various other data deficiencies.

Source: ESE.

Table 2. Carcinogenic Slope Factors and Potential Carcinogenic Effects

Chemical	Carcinogenic Slope Factor (CSF) (mg/kg/day) <sup>-1</sup>	Weight-of-Evidence Classification	Type or Site of Cancer	CSF Basis/CSF Source
Oral	0.0061	B2	Kidney tumors	IRIS, 1996
Inhalation	0.081 <sup>a</sup>	B2	Liver tumors	EPA, 1995

Note: B2 = suspect human carcinogen (sufficient evidence of carcinogenicity in animals and inadequate data in humans).  
UR = unit risk.

<sup>a</sup>Inhalation CSF based on an inhalation UR of  $2.3 \times 10^{-3} (\mu\text{g}/\text{m}^3)^{-1}$  (IRIS, 1996) and assumes that a healthy 70-kilogram adult inhales 20 m<sup>3</sup>/day of air.

Source: ESE.

Table 3. Human Regulatory Criteria (µg/L)

Compound	SDWA			Drinking Water Health Advisories				AWQC		
	Primary MCL	MCL Goal	Secondary MCL	1-Day	10-Day	Longterm	Lifetime	Fish and Water	Fish Only	Water Only <sup>a</sup>
Chloroform	100 <sup>b</sup>	--	--	--	--	--	--	0.19 <sup>c</sup>	15.7 <sup>c</sup>	0.19 <sup>c</sup>

Note: SDWA = EPA Safe Drinking Water Act.  
MCL = maximum contaminant level.  
MCLG = maximum contaminant level goal.  
AWQC = EPA ambient water quality criteria.  
-- = no value available.

\* Value is based on the following formula:

$$\frac{1}{W + F} = \frac{1}{W} + \frac{1}{F}$$

<sup>b</sup> National Interim Primary Drinking Water Regulation (NIPDWR) (45 FR 57332) for total trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane, and bromoform).

<sup>c</sup> Carcinogenic; value represents 10<sup>-6</sup> cancer risk.

Source: ESE.

Table 4. Air Quality Standards

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	9.78 c	--	49 c
STEL	--	9.78 (60 min) c	--
CL	240 c	--	--

Note: TWA = time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect.

STEL = short-term exposure limit; 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any time during a workday even if the 8-hour TWA is not exceeded.

CL = ceiling level; unless otherwise specified, the concentration that should not be exceeded at any time during a workday.

c = designates that this chemical is regulated as a potential carcinogen.

Source: ESE.

Table 5. Ambient Water Quality Standards

LOEL ( $\mu\text{g/L}$ )	Freshwater	Marine
Acute	2,890	--
Chronic	1,240	--

Source: ESE.



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## 1,1-DICHLOROETHANE

(CAS No. 75-34-3)

### INTRODUCTION

1,1-Dichloroethane is currently used as an extractant for heat-sensitive substances, as a cleaning solvent and degreaser, and as a fumigant (ORNL, 1989). The largest industrial use is as an intermediate in the manufacture of 1,1,1-trichloroethane. Previously used as an anesthetic, this practice was stopped because of its marked excitation of the heart (ORNL, 1989).

1,1-Dichloroethane is expected to be highly mobile in the soil/groundwater system because it is soluble in water (5,500 mg/L at 20°C) and has a range of relatively low estimated soil sorption coefficient ( $K_{oc}$ ) values (30 to 58), indicating that the compound will not be strongly bound to soils (ORNL, 1989). Transport of 1,1-dichloroethane vapors through the air-filled pores of unsaturated soils followed by photochemical oxidation is an important loss mechanism for near-surface contaminated soils (ORNL, 1989). In saturated subsurface soils (where soil organic carbon and soil air are negligible), a large fraction of the 1,1-dichloroethane (approximately 90 percent) is expected to be present in the soil-water phase and transported with flowing groundwater (ORNL, 1989). Because 1,1-dichloroethane is a low molecular weight chloroaliphatic, it is not rapidly metabolized in the environment, although it can be degraded by acclimated microbial populations (ORNL, 1989). Under normal environmental conditions, 1,1-dichloroethane is not expected to undergo rapid hydrolysis (ORNL, 1989). Groundwater underlying soils contaminated with 1,1-dichloroethane low organic content may be highly vulnerable to contamination.

### HUMAN HEALTH EFFECTS

#### Noncarcinogenic Effects

EPA has not developed final oral reference doses (RfDs) or inhalation reference concentrations (RfCs) for 1,1-dichloroethane (IRIS, 1996). Interim chronic and subchronic oral and inhalation RfDs are provided by EPA (1995), however, and are presented in Table 1.

The oral RfDs are derived from an inhalation study in which rats, guinea pigs, rabbits, and cats were exposed to inhalation concentrations of 500 ppm (2,025 mg/m<sup>3</sup>) and 1,000 ppm (4,050 mg/m<sup>3</sup>) for 13 weeks (EPA, 1984). Based on this study, a no-observed-effect level (NOEL) for rats of 115 mg/kg/day was determined. Applying an uncertainty factor of 100 (10 for animal-to-human extrapolation and 10 for sensitive human subpopulations) results in an interim subchronic oral RfD of 1.0 mg/kg/day. Applying an additional uncertainty factor of 10 to extrapolate from a subchronic study to chronic exposure results in a chronic oral RfD of 0.1 mg/kg/day.

Based on the same study as the oral RfDs, an inhalation NOEL for cats of 138 mg/kg/day was determined. Using methodology not currently used by EPA's RfD/RfC Work Group, EPA has calculated interim chronic and subchronic inhalation RfCs of 0.5 and 5 mg/m<sup>3</sup>, respectively, for 1,1-dichloroethane (EPA, 1995, Table 2). Assuming that a healthy 70-kilogram adult inhales 20 m<sup>3</sup>/day of air, chronic and subchronic inhalation RfDs of 0.1 and 1 mg/kg/day may be derived.

The available data indicate that 1,1-dichloroethane is capable of causing CNS depression and cardiac arrhythmia and may cause liver damage in humans following inhalation exposure to high doses (EPA, 1985). Short-term acute toxicity tests on laboratory animals indicate that 1,1-dichloroethane is low in acute toxicity but is capable of causing narcosis at high concentrations (ORNL, 1989). Several animal studies suggest that 1,1-dichloroethane has a relatively low potential for causing liver or kidney damage even following repeated exposures (ORNL, 1989). In tests on mice, intraperitoneal doses of 1,000 mg/kg resulted in swelling of the renal tubules of the kidney but no tissue damage (ORNL, 1989). Dermal studies indicate that 1,1-dichloroethane can be absorbed through skin but not in amounts sufficient to produce systemic injury (ORNL, 1989). Chronic inhalation exposures of humans, rats, guinea pigs, and rabbits to 1,1-dichloroethane did not result in toxic effects; however, chronic inhalation exposure of cats resulted in renal damage and signs of renal tubular dilation and degeneration (ORNL, 1989).

#### **Carcinogenicity**

EPA has classified 1,1-dichloroethane as a group C (possible human carcinogen) (IRIS, 1996). This classification is based on no human data and limited evidence of carcinogenicity in two animal species (rats and mice) as shown by an increased incidence of mammary gland adenocarcinomas and hemangiosarcomas in female rats and an increased incidence of hepatocellular carcinomas and benign uterine polyps in mice. Based on these findings, as well as the appearance of lung papillomas in mice after topical treatment, 1,1-dichloroethane was formerly classified as a group B2 chemical, (probable human carcinogen) (EPA, 1990). Because of similarities in structure and target organs, the carcinogenic evidence for 1,2-dichloroethane is considered to be supportive of the re-classification of 1,1-dichloroethane in group C, a possible human carcinogen (IRIS, 1996). No oral or inhalation cancer slope factors (CSFs) were found in the literature reviewed (IRIS, 1996; EPA, 1995).

#### **Mutagenicity**

The compound 1,1-dichloroethane was not mutagenic in the Ames assay, but the conflicting results of the assay indicate that 1,1-dichloroethane may be genotoxic (ORNL, 1989). No other mutagenic data were available in the literature reviewed (IRIS, 1996).

### **Teratogenicity/Reproductive Effects**

No teratogenic effects were observed in rats exposed to 3,380 ppm (15,390 mg/m<sup>3</sup>) 1,1-dichloroethane, but delayed ossification was observed at 6,000 ppm (24,300 mg/m<sup>3</sup>). No effects were observed on implants/dam, live fetuses/dam, resorptions/dam, or fetal weight; however, maternotoxicity was observed in the high-dose group (ORNL, 1989).

### **ECOTOXICITY**

#### **Aquatic organisms**

No information on the effects of 1,1-dichloroethane on aquatic vegetation was found in the reviewed literature.

Concentrations of 11,600 µg/L (LC<sub>50</sub>/EC<sub>50</sub>) affect the aquatic invertebrate *Daphnia magna*. The lowest 96-hour LC<sub>50</sub> reported for fish is 550,000 µg/L, based upon studies of bluegill (*Lepomis macrochirus*) (Verschuere, 1983). The estimated bioconcentration factor of 1.3 indicates insignificant bioconcentration in fish (Lyman *et al.*, 1982).

#### **Terrestrial Organisms**

No information on the effects of 1,1-dichloroethane on terrestrial plants or invertebrates was found in the reviewed literature.

Rats and mice fed relatively high doses of 1,1-dichloroethane showed poor survival. Results were based upon studies using doses of 764 and 382 mg/kg/day (male rats), 950 and 475 mg/kg/day (female rats), 2885 and 1442 mg/kg/day (male mice), and 3331 and 1665 mg/kg/day (female mice) (Clayton and Clayton, 1981). These studies also reported evidence for the carcinogenicity of 1,1-dichloroethane. Reported inhalation LC<sub>50</sub> values are 17,300 ppm in mice after 2 hours and 16,000 ppm in rats after 8 hours (Verschuere, 1983).

### **STANDARDS AND CRITERIA**

#### **Human Receptors**

Although 1,1-dichloroethane is listed in the January 1991 Safe Drinking Water Act (SDWA) Drinking Water Priority List and may be subject to future regulation, EPA has not promulgated or proposed a maximum contaminant level (MCL), an MCL Goal (MCLG), ambient water quality criteria (AWQC), or drinking water health advisories for human consumption of this chemical (IRIS, 1996).

Although inhalation appears to be the primary exposure route for 1,1-dichloroethane, EPA concluded that current information does not indicate that 1,1-dichloroethane endangers public health at ambient concentrations (excluding emergency releases). Therefore, no regulation directed specifically at 1,1-dichloroethane is necessary at this time under the Clean Air Act and no

national ambient air quality standards (NAAQS) have been developed for this volatile chemical (IRIS, 1996). However, the Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure (ACGIH, 1995). In addition, the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable recommended exposure levels (RELs) and threshold limit values (TLVs), respectively (ACGIH, 1995). These values are presented in Table 2.

#### **Ecological Receptors**

EPA has not established AWQCs for 1,1-dichloroethane for the protection of aquatic organisms and lowest observed effect levels (LOELs) or lowest effective concentrations (LECs) are not reported in the available literature (IRIS, 1996).

Table 1. Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects

Chemical	RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/RfD Source	Uncertainty Factors* / (Modifying Factors) <sup>b</sup>
<b>Oral</b>					
Chronic	0.1	--	NOEL	EPA, 1995	1,000 C,H,S
Subchronic	1	--	NOEL	EPA, 1995	100 H,S
<b>Inhalation</b>					
Chronic	0.14	--	Renal damage	EPA, 1995	1,000 C,H,S
Subchronic	1.4	--	Renal damage	EPA, 1995	100 H,S

Note: RfD =  
reference dose.  
-- =  
No EPA Review.

\*Uncertainty factors are typically multiples of 10 and are provided using the following codes:

C =  
to extrapolate from a subchronic study to a chronic endpoint.  
H =  
to extrapolate from an animal study to humans.  
S =  
to protect sensitive human subpopulations.

<sup>b</sup>A modifying factor is an extra safety factor (ranging from 1 to 10) incorporated in the RfD development to account for various other data deficiencies.

Source: ESE.



Table 2. Air Quality Standards

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	400	400	405
STEL	--	--	--
CL	--	--	--

Note: TWA =  
 time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect.

STEL =  
 short-term exposure limit; 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any time during a workday even if the 8-hour TWA is not exceeded.

CL =  
 ceiling level; unless otherwise specified, the concentration that should not be exceeded at any time during a workday.

Source: ESE.

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## 1,1-DICHLOROETHENE

(CAS No. 107-06-2)

### INTRODUCTION

1,1-Dichloroethene, along with vinyl chloride, is primarily used in the production of copolymers with high 1,1-dichloroethene content. It is used primarily in the production of food wraps and flame-retardant fabrics.

1,1-Dichloroethene is considered highly volatile and readily migrates from water and soil to the atmosphere where it is photooxidized by reaction with hydroxyl radicals (EPA, 1985). Based on a soil sorption coefficient ( $K_{oc}$ ) value of 65, this compound is expected to be only weakly sorbed to soils (ORNL, 1989). 1,1-Dichloroethene is not expected to undergo hydrolysis or microbial degradation in natural systems, suggesting that it is persistent (ORNL, 1989). In unsaturated near-surface soils, depending on several factors including the percent organic material, about 60 percent of the compound is expected in the gaseous phase, with only 3 percent in the aqueous phase and the balance sorbed to soil. In the deeper soils, 78 percent of the compound is expected to be in the aqueous phase. That portion of the compound that does not volatilize from the soil may be expected to be mobile in groundwater (ORNL, 1989).

### HUMAN HEALTH EFFECTS

#### Noncarcinogenic

Chronic and subchronic oral reference doses (RfDs) are available from EPA (IRIS, 1996; EPA, 1995a) and are presented in Table 1. Inhalation reference concentrations (RfCs) are currently under review by an EPA Work Group and no inhalation RfCs or RfDs are provided in IRIS (1996) or HEAST (EPA, 1995a).

The oral RfDs were derived from a chronic oral bioassay by Quast *et al.* (1983) in which rats were provided drinking water containing either 50, 100, or 200 mg/L 1,1-dichloroethene. The authors calculated intakes to be 7, 10, and 20 mg/kg/day for male rats and 9, 14, and 30 mg/kg/day for female rats. The female rats evidenced hepatic lesions at all exposure levels, while the males only showed a significant effect at 200 mg/L. Therefore, the lowest-observed-adverse-effect-level (LOAEL) was set at 9 mg/kg-bw/day; a no-observed-adverse-effect-level (NOAEL) could not be determined. Applying an uncertainty factor of 1,000 to the LOAEL (10 for extrapolation of a LOAEL to a NOAEL, 10 for animal-to-human extrapolation, and 10 to protect sensitive subpopulations) results in a chronic oral RfD of 0.009 mg/kg/day.

The results of a 2-year inhalation study indicate that reversible liver damage resulted in rats exposed initially to 10 ppm (39.7 mg/m<sup>3</sup>) for 5 weeks, then to 25 ppm (99.1 mg/m<sup>3</sup>) for 18 months; no other dose-related effects were noted (EPA, 1984). Subchronically, rats exposed to

200 mg/L in their drinking water, which is approximately 35 mg/kg-bw/day, for 90 days evidenced changes in their hepatocytes. No effects were observed in beagle dogs exposed to as much as 25 mg/kg-bw/day (EPA, 1984). In a large experiment in which rats, guinea pigs, rabbits, dogs, and monkeys were exposed to a wide range of inhalation levels for 90 days, weight loss in several species was reported at the lowest exposure level of 5 ppm (20 mg/m<sup>3</sup>); mortality in guinea pigs was reported at the next highest exposure level of 16 ppm (61 mg/m<sup>3</sup>) (EPA, 1984). From this experiment, the lowest exposure of 5 ppm may be considered the LOAEL.

The limited information available on the systemic effects of inhaled 1,1-dichloroethene in humans comes primarily from case reports and/or insufficiently detailed mortality studies wherein the concentration and duration of exposure to 1,1-dichloroethene has not been quantified and concurrent exposure to other toxic substances cannot be ruled out (ATSDR, 1989). With these limitations, available information suggests that short-term inhalation of 1,1-dichloroethene can produce neurotoxicity, while repeated low-level exposure may result in hepatic and renal damage (EPA, 1979; Henschler *et al.*, 1970).

#### Carcinogenicity

1,1-Dichloroethene has been classified by EPA (IRIS, 1996) as a Group C possible human carcinogen via ingestion and inhalation. This classification indicates limited evidence of carcinogenicity in animals with inadequate evidence of human carcinogenicity. Carcinogenic slope factors (CSFs) and supporting information are summarized in Table 2.

EPA has established an oral CSF of 0.6 (mg/kg/day)<sup>-1</sup> (IRIS, 1996) based on a single drinking water study in rats.

An inhalation CSF of 0.175 (mg/kg/day)<sup>-1</sup> was determined based on the results of an inhalation study by Maltoni *et al.* (1985) in which mice were exposed to 10 and 25 ppm for 4-5 days/week for 12 months. A statistically significant increase in kidney adenocarcinoma was noted in male mice. Although statistically significant increases in mammary carcinomas in female mice and pulmonary adenomas in both sexes were reported, dose-response relationships were unclear. A second Maltoni study exposed Sprague Dawley rats to 10, 25, 50, 100, or 150 ppm, 4-5 days/week for 12 months and observed them until spontaneous death. A statistically significant increase in total mammary tumors, but not carcinomas alone, was seen only at 10 and 100 ppm. No dose-response relationship was apparent, and the overall interpretation of the mammary tumor incidence is inconclusive. Based on these studies, an inhalation unit risk (UR) of 5 x 10<sup>-5</sup> (μg/m<sup>3</sup>)<sup>-1</sup> was determined (IRIS, 1996). Assuming a healthy 70-kilogram adult inhales 20 m<sup>3</sup>/day of air, an inhalation CSF of 0.175 (mg/kg/day)<sup>-1</sup> is developed (EPA, 1995b). This UR, and

resulting CSF, should not be used if the air concentration exceeds 200  $\mu\text{g}/\text{m}^3$ , since above this concentration the UR may not be appropriate.

Animal pharmacokinetic data show that metabolite elimination is dose-dependent and saturable at inhalation concentrations of 150-200 ppm, or approximately 50 mg/kg ingestion. Vinylidene chloride is rapidly absorbed, has limited solubility, and is not stored in body tissues.

Pharmacokinetics and metabolism data indicate that the available assays were not of adequate design. The positive Maltoni inhalation study comes closest to achieving a maximum dose of metabolite, albeit less than lifetime exposure. The water CSF based on incidence data from a drinking water study was chosen because route of administration is appropriate to oral risk estimation. The oral CSF should not be used if the water concentration exceeds 600  $\mu\text{g}/\text{L}$ , since above this concentration the CSF may not be appropriate.

### **Mutagenicity**

1,1-Dichloroethene has been determined to be mutagenic to a number of species when in the presence, but not the absence, of a mammalian activating system (EPA, 1984).

1,1-Dichloroethene is mutagenic, and a metabolite is known to alkylate and to bind covalently to DNA. It is structurally related to the known human carcinogen, vinyl chloride (IRIS, 1996).

### **Teratogenicity/Reproductive Effects**

No teratogenic effects were evidenced in rats and rabbits exposed to atmospheres containing up to 160 ppm from day 6 through to parturition, although maternal toxicity and some evidence of fetotoxicity was observed (Murray, 1979). No fetotoxicity was observed in a 3-generation study in which rats were provided drinking water containing up to 200 mg/L (EPA, 1984).

## **ECOTOXICITY**

### **Aquatic Organisms**

EPA (1986) reports an acute concentration of 11,600  $\mu\text{g}/\text{L}$  for the dichloroethenes as the LOEC in aquatic systems. 1,1-Dichloroethene has a relatively low octanol/water partition coefficient (5.37) and a BCF range from 20 to 30, which indicates that 1,1-dichloroethene may not accumulate significantly in animals (Lyman *et al.*, 1982). 1,1-Dichloroethene is not very toxic to freshwater or saltwater fish species, with acute  $\text{LC}_{50}$  values ranging from 80 to 200 mg/L (EPA, 1980). Derived  $\text{LC}_{50}/\text{EC}_{50}$  values for 1,1-dichloroethene are presented in Table 3.

The 96-hour  $\text{LC}_{50}$  for bluegill under static conditions was 73,900  $\mu\text{g}/\text{L}$ . Two 48-hour tests using *Daphnia magna* as the test organism revealed  $\text{EC}_{50}$  values of 11,600 and 79,000  $\mu\text{g}/\text{L}$ . The cause of the differences between the two values could not be ascertained (EPA, 1978, 1980). The 96-hour  $\text{LC}_{50}$  for mysid shrimp exposed to 1,1-dichloroethene was 224,000  $\mu\text{g}/\text{L}$ , and the 96-hour  $\text{LC}_{50}$  value for the sheepshead minnow was 249,000  $\mu\text{g}/\text{L}$  (EPA, 1978).

### **Terrestrial Organisms**

No information was found in the available literature concerning the toxicity of 1,1-dichloroethene to vegetation, livestock, or wildlife.

## **STANDARDS AND CRITERIA**

### **Human Receptors**

A summary of drinking water standards and criteria is presented as Table 4.

EPA has promulgated both the enforceable (for public water supplies) Maximum Contaminant Level (MCL) and the nonenforceable MCL Goal (MCLG) of 7 µg/L for 1,1-dichloroethene based on an RfD and an assumed drinking water contribution of 20% (50 FR 46880; November 13, 1985). The RfD was calculated based on the drinking water equivalent level (DWEL) of 350 µg/L from an animal study in which liver effects were noted. An additional safety factor of 10 (for carcinogenicity) was applied (IRIS, 1996). Due to its carcinogenic ranking, the EPA ambient water quality criterion (AWQC) for the protection of human health should be zero µg/L. However, zero may not be attainable with present technology; therefore, the recommended AWQC for the 10<sup>-5</sup> to the 10<sup>-7</sup> risk levels range from 0.33 to 0.0033 µg/L for consumption of contaminated drinking water and aquatic organisms (IRIS, 1996). For consumption of aquatic organisms only, the recommended AWQC for the 10<sup>-5</sup> to the 10<sup>-7</sup> risk levels range from 18.5 to 0.185 µg/L, respectively (IRIS, 1996). These AWQC would yield values for human consumption of water alone (W) of 0.34, 0.034, and 0.0034 µg/L for 10<sup>-5</sup>, 10<sup>-6</sup>, and 10<sup>-7</sup> risks, respectively, based on the following equation:

$$\frac{1}{W + F} = \frac{1}{W} + \frac{1}{F}$$

No national ambient air quality standards (NAAQS) have been developed for 1,1-dichloroethene. However, the Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure (ACGIH, 1995). In addition, the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable recommended exposure levels (RELs) and threshold limit values (TLVs), respectively (ACGIH, 1995). These values are presented in Table 5.

### **Ecological Receptors**

No AWQCs have been developed for the protection of freshwater or marine organisms against exposure to 1,1-dichloroethene (IRIS, 1995). However, the lowest levels observed to have an effect (LOELs) on the aquatic species tested have been determined for dichloroethenes as a class (IRIS, 1995). These LOELs, which are established when the minimum data required to derive AWQCs are not available, are presented in Table 6.

Table 1. Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects

Chemical	RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/RfD Source	Uncertainty Factors* / (Modifying Factors) <sup>b</sup>
Oral Chronic	0.009	Medium	Hepatic lesions	IRIS, 1995	1,000 H,N,S
Subchronic	0.009	Medium	Hepatic lesions	EPA, 1995a	1,000 H,N,S
Inhalation Chronic	--	--	--	--	--
Subchronic	--	--	--	--	--

Note: IRIS = Integrated Risk Information System.  
RfD = reference dose.  
RfC = reference concentration.  
-- = Not available.  
LOAEL = lowest observed adverse effect level.  
NOAEL = no observed adverse effect level.

\*Uncertainty factors are typically multiples of 10 and are provided using the following codes:

H = to extrapolate from an animal study to humans.  
N = to extrapolate from a LOAEL to a NOAEL.  
S = to protect sensitive human subpopulations.

<sup>b</sup>A modifying factor is an extra safety factor (ranging from 1 to 10) incorporated in the RfD development to account for various other data deficiencies.

Source: ESE.

Table 2. Carcinogenic Slope Factors and Potential Carcinogenic Effects

Chemical	Carcinogenic Slope Factor (CSF) (mg/kg/day) <sup>-1</sup>	Weight-of-Evidence Classification	Type or Site of Cancer	CSF Basis/CSF Source
Oral	0.6	C	--	IRIS, 1995
Inhalation	0.175 <sup>a</sup>	C	Kidney tumors	EPA, 1995b

Note: C = possible human carcinogen (insufficient evidence of carcinogenicity in animals and no data in humans).  
UR = unit risk.

<sup>a</sup>Inhalation CSF based on an inhalation UR of  $5 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$  (IRIS, 1995) and assumes that a healthy 70-kilogram adult inhales 20 m<sup>3</sup>/day of air.

Source: ESE.



Table 3. Acute Toxicity of 1,1-Dichloroethene to Freshwater and Saltwater Organisms

Species	LC <sub>50</sub> /EC <sub>50</sub> (µg/L)	Species Acute Value (µg/L)	Reference
<u>FRESHWATER SPECIES:</u>			
Cladoceran <i>Daphnia magna</i>	11,600	--	Dill <i>et al.</i> , Manuscript
Cladoceran <i>Daphnia magna</i>	79,000	30,300	EPA, 1978
Fathead minnow <i>Pimephales promelas</i>	169,000	--	Dill <i>et al.</i> , Manuscript
Fathead minnow <i>Pimephales promelas</i>	108,000	108,000	Dill <i>et al.</i> , Manuscript
Bluegill <i>Lepomis macrochirus</i>	73,900	73,900	EPA, 1978
Bluegill <i>Lepomis macrochirus</i>	135,000	135,000	EPA, 1978
<u>SALTWATER SPECIES:</u>			
Mysid shrimp <i>Mysidopsis bahia</i>	224,000	224,000	EPA, 1978
Sheepshead minnow <i>Cyprinodon variegatus</i>	249,000	249,000	EPA, 1978

Note: -- = value not available.

Source: ESE.

Table 4. Human Regulatory Criteria (µg/L)

Compound	SDWA			Drinking Water Health Advisories				AWQC		
	Primary MCL	MCL Goal	Secondary MCL	1-Day*	10-Day*	Longterm*	Lifetime	Fish and Water	Fish Only	Water Only*
1,1-Dichloroethene	7	7	--	2,000	1,000	1,000	7	0.033°	1.85°	0.034°

Note: SDWA = EPA Safe Drinking Water Act.  
MCL = maximum contaminant level.  
MCLG = maximum contaminant level goal.  
AWQC = EPA ambient water quality criteria.  
-- = no value available.

\*Value is for a 10-kg child.

°Value is based on the following formula:

$$\frac{1}{W+F} = \frac{1}{W} + \frac{1}{F}$$

°Carcinogenic; value represents 10<sup>-6</sup> cancer risk.

Source: ESE.

Table 5. Air Quality Standards

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	--	c	20 c
STEL	--	c	79 c
CL	--	--	--

Note: TWA = time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect.  
 STEL = short-term exposure limit; 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any time during a workday even if the 8-hour TWA is not exceeded.  
 CL = ceiling level; unless otherwise specified, the concentration that should not be exceeded at any time during a workday.  
 c = designates that this chemical is regulated as a potential carcinogen.

Source: ESE.

Table 6. Ambient Water Quality Standards

LOEL ( $\mu\text{g/L}$ )	Freshwater	Marine
Acute	11,600	224,000
Chronic	--	--

Source: ESE.

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## TETRACHLOROETHENE

(CAS No. 127-18-4)

### INTRODUCTION

Tetrachloroethene, also known as tetrachloroethylene and perchloroethylene, is a colorless, nonflammable liquid with an ethereal, chloroform-like odor. It is produced mainly by the oxyhydrochlorination, perchlorination, and dehydrochlorination of hydrocarbons or chlorinated hydrocarbons such as 1,2-dichloroethane, propylene, propylene dichloride, and 1,1,2-trichloroethane (HSDB, 1996). The major industrial uses of tetrachloroethene are as a solvent, dry-cleaning agent, degreaser, fungicide, insecticide, and nematocide (ReproText, 1996). It is widely distributed in the environment, as evidenced by its detection in trace amounts in most United States' waters and in aquatic organisms, air, food, and human tissue (EPA, 1980). Tetrachloroethene is a common air and groundwater pollutant (ReproText, 1996).

Although found in most environmental media with a vapor pressure of 14 torr at 20°C, tetrachloroethene is sufficiently volatile that it will dissipate rapidly into the air from water and surficial and near-surface soils, where it reacts with hydroxyl radicals. This is probably the most important fate and transport process for tetrachloroethene in the environment. Photolytic degradation in surface waters has been demonstrated, while hydrolysis occurs very slowly (ORNL, 1989). With an estimated soil sorption coefficient ( $K_{oc}$ ) value of 660 and a measured  $K_{oc}$  value of 360, tetrachloroethene will sorb to soils and sediments (ORNL, 1989). In deeper soils where there is little oxygen, about 25 percent of the compound is estimated to solubilize into the groundwater and migrate from the area (ORNL, 1989). Microbial degradation is not believed to be a significant fate, except in biological waste treatment systems where microbes have been acclimated to the compound. Evidence of anaerobic degradation has been reported; however, it appears to be an insignificant pathway (ORNL, 1989).

### HUMAN HEALTH EFFECTS

#### Noncarcinogenic Effects

Chronic and subchronic oral reference doses (RfDs) are available from EPA (IRIS, 1996; EPA, 1995a) and are presented in Table 1. No inhalation reference concentrations (RfCs) or RfDs are provided for either chronic or subchronic exposure.

The oral RfDs are based on a study by Buben and O'Flaherty (1985) in which mice were gavaged with tetrachloroethene in corn oil at doses ranging from 20 to 2,000 mg/kg for 6 weeks. Hepatotoxic effects were first observed at an exposure level of 100 mg/kg-bw/day. This value, converted to 71 mg/kg-bw/day because exposure was only for 5 days per week, was established as the LOAEL. The next lowest dose was 20 mg/kg-bw/day, after converting to 14 mg/kg-bw/day, was designated the NOEL. A NOEL of 14 mg/kg-bw/day was also established in a second study (IRIS, 1996) in which rats were dosed with drinking water at 14, 400, or

1,400 mg/kg-bw/day. Applying an uncertainty factor of 100 (10 for animal-to-human extrapolation and 10 for sensitive human subpopulations) to the NOEL results in an interim subchronic oral RfD of 0.1 mg/kg/day. Applying an additional uncertainty factor of 10 to extrapolate from a subchronic study to chronic exposure results in a chronic oral RfD of 0.01 mg/kg/day.

No information regarding the noncarcinogenic effects in humans following chronic or subchronic oral exposure was found in the available literature. In rats, chronic oral exposure led to toxic nephropathy at TWA intake levels as low as 300 mg/kg-bw/day in mice and 471 mg/kg-bw/day in rats (NCI, 1977). For humans exposed via inhalation, no subchronic information is available, but chronic exposure is reported to lead to respiratory irritation, nausea, sleeplessness, abdominal pain, and constipation (EPA, 1984). EPA (1984) reported liver cirrhosis, hepatitis, and nephritis following exposure, although the exposure levels were not provided. In rats exposed subchronically via inhalation, the liver, kidneys, and spleen evidenced pathologic changes at concentrations as low as 230 ppm; no effects were seen at 70 ppm, which may therefore be designated a NOEL (EPA, 1984). The only chronic nonhuman inhalation information data provided by EPA (1984) concerned unspecified liver damage reported in rats exposed to 600 ppm for a year.

### **Carcinogenicity**

Until 1992, EPA classified tetrachloroethene as a group B2 (probable human) carcinogen for both oral and inhalation exposure routes (EPA, 1991). This classification indicated that sufficient evidence existed to support carcinogenicity in animals, but inadequate evidence existed of carcinogenicity in humans. The data on which oral carcinogenicity was based are presented in an NCI study (1977) in which rats and mice were orally exposed to tetrachloroethene through gavage. The inhalation unit risk was derived from an NTP inhalation study that used mice and rats (EPA, 1995a).

EPA's Carcinogenic Risk Assessment Verification Endeavor (CRAVE) Work Group is currently reviewing studies suggesting that the metabolic pathway responsible for the carcinogenicity of tetrachloroethene in animals may not be present in humans. Therefore, EPA has withdrawn the B2 carcinogenic classification and all CSFs until the new data is evaluated (IRIS, 1996). However, the EPA-NCEA Superfund Health Risk Technical Support Center has developed an interim inhalation CSF of  $0.00203 \text{ (mg/kg/day)}^{-1}$  and an oral CSF of  $0.052 \text{ (mg/kg/day)}^{-1}$  (EPA, 1995b). A summary of the carcinogenic toxicity values is presented in Table 2. No data concerning human carcinogenicity following oral exposure are available and the only available human inhalation data concern dry cleaning workers who were exposed to trichloroethene and carbon tetrachloride as well as tetrachloroethene and no distinction can be made regarding levels of exposure to the three compounds (EPA, 1984).



### **Mutagenicity**

Tetrachloroethene was found to be nonmutagenic in several tests including *Salmonella typhirium* and mouse lymphoma cells with or without metabolic activation (NTP, 1986. ReproText, 1996). Neither sex-linked recessive lethal mutations nor sister chromatid exchanges were induced (NTP, 1986; ReproText, 1996). Tetrachloroethene has been reported to have weak activity in inducing unscheduled DNA synthesis in human cells in culture, in inducing mutations in fruit flies, in abnormal sperm morphology in mice, in chromosome aberrations in rat bone marrow and in a host-mediated microbial assay (ReproText, 1996).

### **Teratogenicity/Reproductive Effects**

Based on the results of a large Scandinavian study of occupational exposures, tetrachloroethene is one of many solvents implicated in increasing the risk of central nervous system effects and structural defects in children following maternal exposure during pregnancy. Because the women were exposed to a number of solvents, it is not possible to attribute these effects to tetrachloroethene alone (ReproText, 1996).

Tetrachloroethene was described as teratogenic in chickens when injected into eggs, but the exposure levels were not presented (ReproText, 1996). Tetrachloroethene was not teratogenic in several rodent inhalation studies (ReproText, 1996). However, some developmental delays and embryotoxicity have been reported at similar levels, including lower weight gains, decreased performance on neuromotor tests, and lower brain levels of acetylcholine and dopamine (HSDB, 1996). Fetotoxicity, fetal and maternal weight depression, and teratogenic effects were reported in rats and mice exposed to inhalation levels of 300 ppm on days 6 to 15 of gestation (EPA, 1984).

## **ECOTOXICITY**

### **Aquatic Organisms**

Lay *et al.* (1984) evaluated the effects on an aquatic system that included nine phytoplankton species. While heterotrophic, mixotrophic, and autotrophic plankton were represented in the test, only the autotrophic evidenced any toxic effects. Water concentrations as low as 440 µg/L were lethal to three species; the fourth survived 1 week. No effects were reported in the other species at levels as high as 1,200 µg/L.

In aquatic systems, EPA (1980) states that the acute and chronic toxicity to freshwater aquatic life occur at 5,280 and 840 µg/L, respectively. Results of acute exposure studies involving freshwater vertebrates and invertebrates are presented in Table 3.

BCFs of 49 and 38.9 were established for bluegill sunfish and fathead minnows (HSDB, 1996). Based on reported and estimated BCFs, tetrachloroethene is not expected to significantly bioconcentrate in aquatic organisms (HSDB, 1996).

### Terrestrial Organisms

For terrestrial vegetation, tetrachloroethene may be expected to act as surmised for chloroform. With a  $K_{ow}$  of 400, tetrachloroethene is partially miscible with water and is likely to cross into the root and be translocated within the plant. As a volatile lipophilic compound, any compound that does not volatilize may cross the cuticle into the plant. No information regarding its toxicological effects is known. Data for determining soil or water TRVs for vegetation are insufficient.

In the early part of the twentieth century, tetrachloroethene was used as an anthelmintic compound against hookworms in humans and animals (Roberson, 1977; Negherbon, 1959). Similar in action to carbon tetrachloride, it is reported to be better tolerated, in general, by most animals (Clarke and Clarke, 1975). Acute symptoms are those associated with central nervous system (CNS) toxicity, including dizziness and incoordination with occasional vomiting. If sufficient exposure occurs, this may lead to coma, circulatory collapse, and death. Liver and kidney damage have been reported following exposure to large doses that approached near-lethal levels (Klaassen and Plaa, 1966). Data concerning toxicity to terrestrial organisms are presented in Table 4.

## **STANDARDS AND CRITERIA**

### Human Receptors

A summary of drinking water standards and criteria is presented as Table 5. Due to the former ranking of tetrachloroethene as a Group B2 suspect human carcinogen, EPA set a nonenforceable Maximum Contaminant Level Goal (MCLG) for drinking water of zero  $\mu\text{g/L}$  and a Maximum Contaminant Level (MCL) of 5  $\mu\text{g/L}$ , which is enforceable for public water supplies (52 FR 25690, 7/08/87). Also due to its carcinogenic ranking, the EPA ambient water quality criterion (AWQC) for the protection of human health should be zero  $\mu\text{g/L}$ . However, zero may not be attainable with present technology; therefore, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 8 to 0.08  $\mu\text{g/L}$  for consumption of contaminated drinking water and aquatic organisms (IRIS, 1996). For consumption of aquatic organisms only, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 88.5 to 0.885  $\mu\text{g/L}$ , respectively (IRIS, 1996). These AWQC would yield values for human consumption of water alone (W) of 8.8, 0.88, and 0.088  $\mu\text{g/L}$  for  $10^{-5}$ ,  $10^{-6}$ , and  $10^{-7}$  risks, respectively, based on the following equation:

$$\frac{1}{W+F} = \frac{1}{W} + \frac{1}{F}$$

If EPA determines tetrachloroethene to be a Group C carcinogen or noncarcinogenic in humans, the MCL of 5  $\mu\text{g/L}$ , the MCLG of 0  $\mu\text{g/L}$ , and the AWQCs will most likely be raised, since these drinking water values are based on potential carcinogenic effects in humans.

EPA has not established regulations for tetrachloroethene under the Clean Air Act and no national ambient air quality standards (NAAQS) have been developed (IRIS, 1996). However, the Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure, (ACGIH, 1995). In addition, the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable threshold limit values (TLVs) (ACGIH, 1995). These values are presented Table 6.

#### **Ecological Receptors**

EPA AWQCs for the protection of freshwater and marine organisms are presented in Table 7 (IRIS, 1996). The values reported are not criteria, but are the lowest effect concentrations (LECs) found in the literature. LECs are given when the minimum data required to derive water quality criteria are not available (IRIS, 1996).

Table 1. Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects

Chemical	RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/RfD Source	Uncertainty Factors* / (Modifying Factors) <sup>b</sup>
Oral Chronic	0.01	Medium	Liver lesions	IRIS, 1996	1,000 C,H,S
Subchronic	0.1	Medium	Liver lesions	EPA, 1995a	100 H,S
Inhalation Chronic	--	--	--	--	--
Subchronic	--	--	--	--	--

Note: RfD =  
reference dose.  
-- =  
No EPA Review.

\*Uncertainty factors are typically multiples of 10 and are provided using the following codes:

C =  
to extrapolate from a subchronic study to a chronic endpoint.  
H =  
to extrapolate from an animal study to humans.  
S =  
to protect sensitive human subpopulations.

<sup>b</sup>A modifying factor is an extra safety factor (ranging from 1 to 10) incorporated in the RfD development to account for various other data deficiencies.

Source: ESE.

Table 2. Carcinogenic Slope Factors and Potential Carcinogenic Effects

Chemical	Carcinogenic Slope Factor (CSF) (mg/kg/day) <sup>-1</sup>	Weight-of-Evidence Classification	Type or Site of Cancer	CSF Basis/CSF Source
Oral	0.052	B2	Liver tumors	EPA, 1995b
Inhalation	0.00203	B2	Liver tumors	EPA, 1995b

Note: B2 = suspect human carcinogen (sufficient evidence of carcinogenicity in animals and inadequate data in humans).  
UR = unit risk.

Source: ESE.

Table 3. Toxicity of Tetrachloroethene to Aquatic Organisms

Species	Concentration (mg/L)	Effect	Reference
Guppy ( <i>Poecilia reticulata</i> )	18.0	LC <sub>50</sub>	HSDB, 1996
Fathead minnow ( <i>Pimephales promelas</i> )	18.4	LC <sub>50</sub>	HSDB, 1996
Bluegill ( <i>Lepomis macrochirus</i> )	13.0	LC <sub>50</sub>	HSDB, 1996
Water flea ( <i>Daphnia magna</i> )	18.0	LC <sub>50</sub>	HSDB, 1996
Rainbow trout ( <i>Salmo gairdneri</i> )	5.0	LC <sub>50</sub>	HSDB, 1996
Dab ( <i>Limanda limanda</i> )	5.0	LC <sub>50</sub>	HSDB, 1996
Midge ( <i>Tanytarsus dissimilis</i> )	0.03	LC <sub>50</sub>	HSDB, 1996
Mysid shrimp ( <i>Mysidopsis bahia</i> )	10.2	LC <sub>50</sub>	EPA, 1978
Sheepshead minnow ( <i>Cyprinodon variegatus</i> )	29.4	LC <sub>50</sub>	EPA, 1978

Source: ESE.

Table 4. Toxicity of Tetrachloroethene to Terrestrial Organisms

Organism	Concentration (mg/L)	Effect	Reference
Cat	4,000	LD <sub>Lo</sub>	RTECS, 1996
Calf	0.14	Liver Damage	Schlingman and Gruhzit, 1926
Calf	0.25	Liver and Kidney Damage	Schlingman and Gruhzit, 1926
Chicken	1.0	LOAEL	Schlingman and Gruhzit, 1926
Dog	4,000	LD <sub>Lo</sub>	RTECS, 1996
Horse	0.11	Liver Effects	Schlingman and Gruhzit, 1926
Mouse	8,100	LD <sub>50</sub>	RTECS, 1996
Mouse	71	LOAEL	IRIS, 1996
Pig	1.0	LOAEL	Schlingman and Gruhzit, 1926
Rabbit	5,000	LD <sub>Lo</sub>	RTECS, 1996
Rat	2,630	LD <sub>50</sub>	RTECS, 1996
Rat	14	NOAEL	IRIS, 1996
Sheep	0.36	Minor Liver Effects	Schlingman and Gruhzit, 1926

Source: ESE

Table 5. Human Regulatory Criteria (µg/L)

Compound	SDWA			Drinking Water Health Advisories				AWQC		
	Primary MCL	MCL Goal	Secondary MCL	1-Day	10-Day	Longterm	Lifetime	Fish and Water	Fish Only	Water Only*
Tetrachloroethene	5.0	0	--	--	2,000	1,400	10	87	14.1	--

Note: SDWA = EPA Safe Drinking Water Act.  
MCL = maximum contaminant level.  
MCLG = maximum contaminant level goal.  
AWQC = EPA ambient water quality criteria.  
-- = no value available.

\*Value is based on the following formula:

$$\frac{1}{W + F} = \frac{1}{W} + \frac{1}{F}$$

Source: ESE.



Table 6. Air Quality Standards

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	170	c	170
STEL	--	c	685
CL	2,040 (5 min peak in any 3 hours)	--	--

Note: TWA = time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect.

STEL = short-term exposure limit; 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any time during a workday even if the 8-hour TWA is not exceeded.

CL = ceiling level; unless otherwise specified, the concentration that should not be exceeded at any time during a workday.

c = designates that this chemical is regulated as a potential carcinogen.

Source: ESE.

Table 7. Ambient Water Quality Criteria ( $\mu\text{g/L}$ )

AWQC ( $\mu\text{g/L}$ )	Freshwater	Marine
Acute	5,280	10,200
Chronic	840	450

Source: ESE.

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## 1,1,1-TRICHLOROETHANE

(CAS No. 71-55-6)

### INTRODUCTION

1,1,1-Trichloroethane is widely used as a cleaning solvent because of its nonflammability and solvent properties and in aerosols because of its volatility. It is also used as a coolant and lubricant in metal cutting oils, in inks and drain cleaners, and as a chemical intermediate in the production of 1,1-dichloroethylene.

With a solubility in water of 4,400 mg/L (Verschuere, 1983), 1,1,1-trichloroethane is considered water soluble. This compound is also highly volatile in aqueous systems and disperses from surface water primarily by volatilization to the atmosphere, where it is photooxidized by reaction with hydroxyl radicals (ORNL, 1989). Transport of vapors through the air-filled pores of unsaturated soils is an important pathway for near-surface soils (Pavlou, 1980). Alternatively, evidence exists that a moderate degree of sorption to soils, sediments, and organic material occurs, based on the value of 152 reported for the soil sorption coefficient ( $K_{oc}$ ) (EPA, 1986). The combined water solubility, soil sorption, and organic partitioning data suggest that this compound may volatilize from soil surfaces, but that the portion not removed by volatilization will exhibit some degree of environmental mobility (Pavlou, 1980).

### HUMAN HEALTH EFFECTS

#### Noncarcinogenic Effects

EPA has withdrawn the chronic oral reference dose (RfD) and chronic inhalation reference concentration (RfC) for 1,1,1-trichloroethane pending further evaluation (IRIS, 1996; EPA, 1995a). However, chronic oral and inhalation RfDs of 0.09 and 0.29 mg/kg/day, respectively, are provided in the latest version of EPA Region III's Risk-Based Concentration Table (EPA, 1995b) and are presented in Table 1. No subchronic oral or inhalation toxicity values were located in the available literature (EPA, 1995a).

1,1,1-Trichloroethane is a central nervous system (CNS) and respiratory depressant, as well as a skin and mucous membrane irritant. Like many solvents, 1,1,1-trichloroethane will defat the skin, causing redness and scaliness. Absorption through the skin can occur but is not a significant route of toxic exposure. 1,1,1-Trichloroethane is one of the least toxic of the chlorinated hydrocarbons used as a solvent (HazardText, 1996). Over the last few years, instances of 1,1,1-trichloroethane toxicity have increased due to the use of the substance as a mind-altering drug. An overdose via inhalation may produce unconsciousness, seizures, respiratory arrest, and even cardiovascular abnormalities. Numerous reports have apparently described sudden death after sniffing 1,1,1-trichloroethane. Human systemic effects by ingestion and inhalation include conjunctival irritation, hallucinations or distorted perceptions, motor activity changes, irritability,

aggression, hypermotility, diarrhea, nausea or vomiting and other gastrointestinal changes (HazardText, 1996).

1,1,1-Trichloroethane is rapidly absorbed by ingestion, inhalation, and through the skin. In acute exposures it produces a pattern of skin, eye, and respiratory irritation, and of CNS depression. Symptoms of CNS depression include headache, weakness, dizziness, nausea, loss of coordination and judgement, with coma and death at higher doses. Short-term exposures of 250 to 550 ppm increased reaction time and impaired manual dexterity (Clayton and Clayton, 1981). At 1,000 ppm, equilibrium was disturbed. At 1,900 to 2,650 ppm there was irritation of the throat and light-headedness, headache and lassitude. Concentrations greater than 5,000 ppm are regarded as life-threatening, with 6000 to 20,000 ppm conferring risk of a sudden death syndrome (Droz *et al.*, 1982).

1,1,1-Trichloroethane is known from controlled studies in dogs to be a cardiac sensitizer, which involves increasing the sensitivity of the heart to epinephrine with resulting arrhythmias and fibrillation (Reinhardt *et al.*, 1973). The cardiac effects of 1,1,1-trichloroethane may play a role in cases of sudden death from exposure to high concentrations. Generally death from exposure to concentrations greater than 5,000 ppm is due to respiratory arrest (a consequence of its CNS depressant effects) and to peripheral vascular collapse (HSDB, 1996).

When repeatedly applied to the skin, trichloroethane has a defatting action. Voluntary exposure to 500 ppm 1,1,1-trichloroethane in repeated exposures caused fatigue. The 1,1,1-trichloroethane equilibrated in the subjects after 3 to 4 days, but was still detectable in the breath up to 1 month after exposure ceased (Stewart *et al.*, 1969). It is possible that some of the sudden deaths from occupational exposure to 1,1,1-trichloroethane may involve a chronic component of its toxicity, particularly in relation to its role as a cardiac sensitizer (King *et al.*, 1985).

Limited chronic human inhalation data suggest disruption of CNS functions in individuals exposed to 350 ppm for 3 hours (EPA, 1984). The only available chronic inhalation study using experimental animals resulted in focal hepatocellular changes in female rats exposed to air concentrations of 1,750 ppm over a 12-month period (EPA, 1984); the next highest exposure level of 875 ppm appeared to represent a NOEL for the study.

### **Carcinogenicity**

EPA has classified 1,1,1-trichloroethane as a group D (not classifiable) carcinogen (IRIS, 1996). This classification was given to this compound because there are no reported human data, and animal studies (one lifetime gavage and one intermediate inhalation) have not demonstrated carcinogenicity.

### **Mutagenicity**

Laboratory results on the mutagenic effects of 1,1,1-trichloroethane on various species are equivocal or confused. Only a few *Salmonella typhirium* strains evidenced a positive reaction for mutagenicity when exposed to 1,1,1-trichloroethane (EPA, 1984). An isomer, 1,1,2-trichloroethane, is carcinogenic in mice, inducing liver cancer and pheochromocytomas in both sexes. Dichloroethanes, tetrachloroethanes, and hexachloroethane also produced liver cancer in mice and other types of neoplasms in rats. It should be noted that 1,4-dioxane, a known animal carcinogen that causes liver and nasal tumors in more than one strain of rats and hepatocellular carcinomas in mice, is a contaminant of technical-grade 1,1,1-trichlorethane (IRIS, 1996).

### **Teratogenicity/Reproductive Effects**

No teratogenicity was observed in pregnant rats or mice exposed to 875 ppm on days 6 to 15 of gestation (Schwetz *et al.*, 1984). In experiments using mice and oral doses of 1,1,1-trichloroethane up to 1,000 mg/kg/day, no effects on fertility, gestation, viability, lactation, or survival and weight gain of the offspring were observed (Lane *et al.*, 1982). Rats given 2100 ppm 1,1,1-trichloroethane by inhalation had offspring with lower fetal weights and delayed development of bones and kidneys, findings not regarded as teratogenic by the authors (York *et al.*, 1982). This study was interpreted by the authors as showing embryotoxic effects of 1,1,1-trichloroethane.

The body of evidence in animal studies suggests that trichloroethane is not a reproductive hazard even at high doses.

## **ECOTOXICITY**

### **Aquatic Organisms**

No information of the effects of 1,1,1-trichloroethane on aquatic plants or invertebrates was found in the reviewed literature.

In fish, the lowest 96-hour  $LC_{50}$  reported was 52,800  $\mu\text{g/L}$  for fathead minnow (*Pimephales promelas*), whereas an effective concentration ( $EC_{50}$ ) of 11,100  $\mu\text{g/L}$  was reported for juveniles (Alexander *et al.*, 1978). Juvenile bluegill sunfish (*Lepomis machrochirus*) had a 96-hour  $LC_{50}$  of 40,000  $\mu\text{g/L}$  (Buccafusco *et al.*, 1981) and bioconcentration of 1,1,1-trichloroethane has also been reported for this species (Barrows *et al.*, 1980; Davies and Dobbs, 1984).

### **Terrestrial Organisms**

No information on the effects of 1,1,1-trichloroethane on terrestrial plants or invertebrates was found in the reviewed literature.

Oral doses of 750 and 1,500 mg/kg/day administered to rats resulted in respiratory and other problems and, ultimately, death in all but 3% of the rats treated (NCI, 1977). Single oral doses of 5,660 mg/kg were lethal ( $LD_{50}$ ) to female rabbits whereas doses of 9,470 mg/kg were lethal to male guinea pigs (Verschuieren, 1983). Continuous exposure to air containing up to 370 ppm for 90 days or 2200 ppm for 8 hours, 5 days/week over a period of 6 weeks produced no symptoms of toxicity in rats, guinea pigs, squirrel monkeys, rabbits, and dogs (Prendergast et al., 1967). Inhalation of air containing 24,000 ppm for 1 hour to 14,000 ppm for 7 hours was lethal to rats ( $LC_{50}$ ) whereas the reported  $LC_{50}$  for mice was 13,500 ppm for 10 hours (Verschuieren, 1983).

Rats tolerated 204 ppm for 3 months with no apparent ill effects (Eben and Kimmerle, 1974). Rats exposed to 1,1,1-trichloroethane at 500 to 4000 ppm for 4 days showed withdrawal syndrome characterized by handling-induced convulsions upon removal from exposure. Re-exposure to 1,1,1-trichloroethane reduced the severity of the convulsions, and toluene, ethanol, pentobarbital, or midazolam were also effective in reducing effects of withdrawal. These results suggest that 1,1,1-trichloroethane can induce physical dependence similar to that of CNS-depressant drugs (Evans and Balster, 1993).

Rats exposed to 1,1,1-trichloroethane by inhalation at concentrations up to 2,000 ppm for 13 weeks showed no changes in neurologic function, as determined by a functional observational battery, or clinical or morphologic findings, except for diminished forelimb grip performance in the 2000 ppm group (Mattsson *et al.*, 1993).

## STANDARDS AND CRITERIA

### Human Receptors

A summary of drinking water standards and criteria is presented as Table 2. EPA has promulgated an enforceable (for public water supplies) Maximum Contaminant Level (MCL) and a nonenforceable MCL Goal (MCLG) for drinking water of 200  $\mu\text{g/L}$  (56 FR 30266).

Although inhalation appears to be the primary exposure route for 1,1,1-trichloroethane, EPA concluded that current information does not indicate that 1,1,1-trichloroethane endangers public health at ambient concentrations (excluding emergency releases). Therefore, no regulation directed specifically at 1,1,1-trichloroethane is necessary at this time under the Clean Air Act and no national ambient air quality standards (NAAQS) have been developed for 1,1,1-trichloroethane (IRIS, 1996). However, the Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure (ACGIH, 1995). In addition, the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable



recommended exposure levels (RELs) and threshold limit values (TLVs), respectively (ACGIH, 1995). These values are presented in Table 3.

TWA is the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect. The short-term exposure limit, or STEL, is the 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any any time during a workday even if the 8-hour TWA is not exceeded. The ceiling level, or CL, unless otherwise specified is the concentration that should not be exceeded at any any time during a workday. The "s" after the criteria value designates that the listed agencies consider exposure through the skin, mucous membranes, and/or eyes to be a potential significant exposure route.

#### **Ecological Receptors**

No AWQCs have been developed for the protection of freshwater or marine organisms against exposure to 1,1,1-trichloroethane (IRIS, 1996). However, a concentration of 31,200  $\mu\text{g/L}$  was the lowest level observed to have an acute effect (LOEL) on the marine species tested (IRIS, 1996). LOELs are established when the minimum data required to derive AWQCs are not available. In addition, an acute freshwater LOEL of 18,000  $\mu\text{g/L}$  was observed for trichlorinated ethanes as a class of chemicals (IRIS, 1996).

Table 1. Noncarcinogenic Reference Doses and Potential Noncarcinogenic Effects

Chemical	RfD (mg/kg/day)	Confidence Level	Critical Effect	RfD Basis/RfD Source	Uncertainty Factors* / (Modifying Factors) <sup>b</sup>
Oral					
Chronic	0.09 <sup>c</sup>	--	Liver toxicity	EPA, 1995b	1,000 C,H,S
Subchronic	--	--	--	--	--
Inhalation					
Chronic	0.29 <sup>c</sup>	--	Liver toxicity	EPA, 1995b	1,000 C,H,S
Subchronic	--	--	--	--	--

Note: IRIS = Integrated Risk Information System.  
RfD = reference dose.  
RfC = reference concentration.  
-- = Not available.

\*Uncertainty factors are typically multiples of 10 and are provided using the following codes:

C = to extrapolate from a subchronic study to a chronic endpoint.

H = to extrapolate from an animal study to humans.

S = to protect sensitive human subpopulations.

<sup>b</sup> A modifying factor is an extra safety factor (ranging from 1 to 10) incorporated in the RfD development to account for various other data deficiencies.

<sup>c</sup> EPA has withdrawn this value from IRIS.

Source: ESE.

Table 2. Drinking Water Criteria and Standards (µg/L)

Compound	SDWA			Drinking Water Health Advisories				AWQC		
	Primary MCL	MCL Goal	Secondary MCL	1-Day <sup>a</sup>	10-Day <sup>a</sup>	Longterm <sup>a</sup>	Lifetime	Fish and Water	Fish Only	Water Only <sup>b</sup>
1,1,1-Trichloroethane	200	200	--	100,000	40,000	40,000	200	18,400	1,030,000	18,700

Note: SDWA = EPA Safe Drinking Water Act.  
MCL = maximum contaminant level.  
MCLG = maximum contaminant level goal.  
AWQC = EPA ambient water quality criteria.

<sup>a</sup>Value is for a 10-kg child.

<sup>b</sup>Value is based on the following formula:

$$\frac{1}{W + F} = \frac{1}{W} + \frac{1}{F}$$

Source: ESE.

Table 3. Air Quality Criteria

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	1,900	--	1,910
STEL	2,450	--	2,460
CL	--	1,910 (15 min)	--

Source: ESE.

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## TRICHLOROETHENE

(CAS No. 79-01-6)

### INTRODUCTION

Trichloroethene (TCE) is widely used as an industrial solvent, particularly in metal degreasing (ORNL, 1989). It is also used in a variety of miscellaneous applications such as a low-temperature heat exchange fluid, as a fumigant, as a diluent in paints and adhesives, in aerospace operations, i.e., to flush liquid oxygen, and in textile processing (ORNL, 1989). It was previously used as an extractant in food processing and as an anesthetic, but it is no longer used for these purposes because of possible carcinogenic activity (ORNL, 1989).

TCE is expected to be relatively mobile in the soil/groundwater system as, at 1,000 mg/L at 20°C, it is soluble in water. TCE has a low soil sorption coefficient ( $K_{oc}$ ) which, with an estimated value of 127 and a log octanol-water partition coefficient ( $\log K_{ow}$ ) of 2.42, indicates that it will not be strongly bound to soils (ORNL, 1989). Based on the vapor pressure of 60 torr at 20°C, transport of TCE vapors through the air-filled pores of unsaturated soils followed by photooxidation is an important loss mechanism for near-surface contaminated soils (ORNL, 1989). Upon reaching the atmosphere from surface waters and soil surfaces, TCE reacts with hydroxyl radicals to produce hydrochloric acid, carbon monoxide, carbon dioxide, and carboxylic acid (EPA, 1985a). In saturated subsurface soils (where soil organic carbon and soil air are negligible), a much higher fraction of the TCE is expected to be present in the soil-water phase and transported with flowing groundwater (ORNL, 1989). Because TCE is a low molecular weight chloroaliphatic, it is not rapidly metabolized in the environment, although it can be degraded by acclimated microbial populations (ORNL, 1989). Under normal environmental conditions, TCE is not expected to undergo rapid hydrolysis (ORNL, 1989).

### HUMAN HEALTH EFFECTS

#### Noncarcinogenic Effects

EPA has not derived any chronic or interim subchronic oral reference doses (RfDs) or inhalation reference concentrations (RfCs) for TCE (IRIS, 1996; EPA, 1995a). However, the EPA-NCEA Superfund Health Risk Technical Support Center of the Environmental Criteria and Assessment Office (ECAO) has developed a provisional chronic oral RfD, which has been adopted by EPA Region III (1995b) and is presented in Table 1. Based on a subchronic oral no-observed-adverse-effect level (NOAEL) in mice of 18.4 mg/kg/day and applying an uncertainty factor of 3,000 (10 for sensitive human subpopulations, 10 for animal-to-human extrapolation, 10 for extrapolation from a subchronic study to a chronic endpoint, and 3 to account for deficiencies in the database), a provisional chronic oral RfD of 0.006 mg/kg/day is derived (EPA, 1993). No data are available for developing an inhalation RfD for TCE (IRIS, 1996).



Animal studies indicate that TCE is capable of causing kidney and liver damage, neurotoxicity, and dermatological reactions following chronic inhalation exposure to levels greater than 2,000 mg/m<sup>3</sup> for 6 months. NIOSH reported a lowest observed lethal concentration for humans of 2,900 ppm (15,600 mg/m<sup>3</sup>) after acute inhalation exposure (ATSDR, 1988).

Effects of short-term human exposure include mild eye irritation, nausea, vertigo, headache and confusion. Unconsciousness and death may occur following exposure to excessive concentrations (ATSDR, 1988). Chronic oral exposure of humans to TCE is characterized by dizziness, nausea, headache, ataxia, decreased appetite, and sleep disturbances (ATSDR, 1988). The acute oral toxicity of TCE is low in animals as indicated by acute oral LD<sub>50</sub> values that range from 2,400 mg/kg for a mouse to 7,330 mg/kg for a rabbit (ATSDR, 1988). The acute LD<sub>50</sub> for the rat is reported as 4,920 mg/kg (EPA, 1985b). Increased organ and body weights and increased protein and ketones in urine were observed in mice exposed to levels between 660 and 790 mg/kg/day (USATHAMA, 1989). EPA (1984) reported 18 mg/kg/day as the NOEL for TCE.

#### **Carcinogenicity**

Until 1989, EPA classified TCE as a group B2 (probable human) carcinogen (EPA, 1993). This classification indicated that sufficient evidence existed to support carcinogenicity in animals but inadequate evidence existed of carcinogenicity in humans. The results of several mouse bioassays indicated an increased incidence of liver tumors following oral gavage exposure and an increased incidence of lung tumors following inhalation exposure (EPA, 1984). Through 1989, EPA had listed cancer slope factors (CSFs) for oral and inhalation exposure to TCE of 0.011 and 0.017 (mg/kg/day)<sup>-1</sup>, respectively (EPA, 1991).

EPA's Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work Group is currently reviewing studies suggesting that the metabolic pathway responsible for the carcinogenicity of TCE in animals may not be present in humans. Therefore, EPA has withdrawn the B2 carcinogenic classification and all CSFs until the new TCE data is evaluated (IRIS, 1996). For comparison purposes, the former oral CSF of 0.011 (mg/kg/day)<sup>-1</sup> may be used (EPA, 1995b). However, EPA-NCEA has developed an interim inhalation CSF of 0.006 (mg/kg/day)<sup>-1</sup>. This value has been adopted by EPA Region III and replaces the higher value of 0.017 (mg/kg/day)<sup>-1</sup> (EPA, 1995b).

#### **Mutagenicity**

Positive to weakly positive responses have been noted in a mammalian transformation and in bacterial and yeast test systems (ORNL, 1989). In addition positive responses were observed in an in vivo spot test mutation assay in mice (ORNL, 1989). Weakly positive responses have been

observed in a sister chromatid exchange study, but no increase in chromosome aberrations were observed (ORNL, 1989).

#### Teratogenicity/Reproductive Effects

No epidemiological studies of congenital anomalies in children born to women exposed to TCE during pregnancy have been reported (TERIS, 1996).

Developmental toxicity studies with TCE indicate that it is fetotoxic but is neither mutagenic nor teratogenic to rodents following inhalation exposure. However, one of the potential intermediate metabolites, chloral hydrate, is mutagenic. No fetotoxicity or teratogenicity was reported in pregnant mice and rats exposed to air levels of 300 ppm for 7 hours/day on gestational days 6 through 15 (Shepard, 1996). However, anomalies of skeletal and soft tissues indicative of developmental delay were reported in offspring of pregnant rats exposed to 1,800 ppm for 6 hours/day for 2 weeks before pregnancy and the first 20 days of gestation (Shepard, 1996). Other effects related to TCE exposure include delayed ossification of the skeleton, increases in resorptions and decreases in the fetal body weights of rats (ATSDR, 1988). Increased sperm abnormalities were reported in mice exposed to 3,000 ppm for 4 hours/day for 5 days (Shepard, 1996). This latter concentration is 50 percent greater than the reported chronic toxic value.

### **ECOTOXICITY**

#### Aquatic Organisms

Static tests with *Daphnia magna* resulted in 48-hour EC<sub>50</sub> values ranging from 41,000 to 100,000 µg/L (EPA, 1980). TCE is acutely toxic to *D. magna* at levels 85.2 mg/L in a static 48-hr LC<sub>50</sub> test (EPA, 1978) (see Table 1). Chronic tests indicated no adverse effects on *D. magna* at 10 mg/L, the highest level tested (EPA, 1978). In a natural pond, doses of 0.025 and 0.110 µg/L decreased *D. magna* populations but increased phytoplankton populations (Lay *et al.*, 1984). Tests with *Daphnia pulex* provided values ranging from 39,000 to 51,000 µg/L (EPA, 1980). In flow-through tests with the fathead minnow, the 96-hour LC<sub>50</sub> was 40,700 µg/L, while the value associated with static tests was 66,800 µg/L; fathead minnows evidenced loss of equilibrium at 21,900 µg/L (USATHAMA, 1989). The 96-hour LC<sub>50</sub> for bluegill was 44,700 µg/L (USATHAMA, 1989). EPA reports LOECs for acute and chronic exposures to TCE of 45,000 and 21,900 µg/L, respectively (IRIS, 1996). Applying an uncertainty factor of 10 to the chronic freshwater LOEC provides a water toxicity reference value (TRV) of 2,200 µg/L for aquatic organisms.

TCE does not accumulate in aquatic organisms to any great extent. A BCF of 17 for bluegill (*Lepomis macrochirus*) was observed after an exposure duration of 14 days (EPA, 1978). The biological half-life is less than 1 day, suggesting that residue accumulation is not a concern for aquatic life (EPA, 1980).

### Terrestrial Organisms

No data regarding the toxicity of TCE to vegetation were identified in the available literature. No data concerning the toxicity of TCE to domestic livestock or terrestrial wildlife were identified.

## **STANDARDS AND CRITERIA**

### Human Receptors

A summary of drinking water standards and criteria is presented as Table 2. Due to the former ranking of TCE as a Group B2 suspect human carcinogen, EPA set a nonenforceable Maximum Contaminant Level Goal (MCLG) for drinking water of zero  $\mu\text{g/L}$  and a Maximum Contaminant Level (MCL) of 5  $\mu\text{g/L}$ , which is enforceable for public water supplies (52 FR 25690, 7/08/87). Also due to its carcinogenic ranking, the EPA ambient water quality criterion (AWQC) for the protection of human health should be zero  $\mu\text{g/L}$ . However, zero may not be attainable with present technology; therefore, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 27 to 0.27  $\mu\text{g/L}$  for consumption of contaminated drinking water and aquatic organisms (IRIS, 1996). For consumption of aquatic organisms only, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 807 to 8.07  $\mu\text{g/L}$ , respectively (IRIS, 1996). These AWQC would yield values for human consumption of water alone (W) of 28, 2.8, and 0.28  $\mu\text{g/L}$  for  $10^{-5}$ ,  $10^{-6}$ , and  $10^{-7}$  risks, respectively, based on the following equation:

$$\frac{1}{W+F} = \frac{1}{W} + \frac{1}{F}$$

If EPA determines TCE to be a Group C carcinogen or noncarcinogenic in humans, the MCL of 5  $\mu\text{g/L}$ , the MCLG of 0  $\mu\text{g/L}$ , and the AWQCs will most likely be raised, since these drinking water values are based on potential carcinogenic effects in humans.

No national ambient air quality standards (NAAQS) have been developed for TCE. However, the Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure (ACGIH, 1995). In addition, the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable recommended exposure levels (RELs) and threshold limit values (TLVs), respectively (ACGIH, 1995). These values are presented in Table 3.

### Ecological Receptors

No AWQCs have been developed for the protection of freshwater or marine organisms against exposure to TCE (IRIS, 1996). However, the lowest levels observed to have an effect (LOELs) on the aquatic species tested have been determined (IRIS, 1996). These LOELs, which are

established when the minimum data required to derive AWQCs are not available, are presented in Table 4.

Table 1. Acute Toxicity of TCE to Freshwater Organisms

Species	LC <sub>50</sub> /EC <sub>50</sub> (μg/L)	Species Acute Value (μg/L)	Reference
<b><u>FRESHWATER SPECIES:</u></b>			
Cladoceran <i>Daphnia magna</i>	85,200	--	EPA, 1978
Cladoceran <i>Daphnia magna</i>	100,000	--	Canton and Adema, 1978
Cladoceran <i>Daphnia magna</i>	94,000	--	Canton and Adema, 1978
Cladoceran <i>Daphnia magna</i>	41,000	--	Canton and Adema, 1978
Cladoceran <i>Daphnia magna</i>	43,000	--	Canton and Adema, 1978
Cladoceran <i>Daphnia magna</i>	55,000	--	Canton and Adema, 1978
Cladoceran <i>Daphnia magna</i>	56,000	64,000	Canton and Adema, 1978
Cladoceran <i>Daphnia pulex</i>	51,000	--	Canton and Adema, 1978
Cladoceran <i>Daphnia pulex</i>	39,000	45,000	Canton and Adema, 1978
Fathead minnow <i>Pimephales promelas</i>	40,700	--	Alexander <i>et al.</i> , 1978
Fathead minnow <i>Pimephales promelas</i>	66,800	40,700	Alexander <i>et al.</i> , 1978
Bluegill <i>Lepomis macrochirus</i>	44,700	44,700	EPA, 1978

Note: -- = value not available.

Source: ESE.

Table 2. Human Regulatory Criteria (µg/L)

Compound	SDWA			Drinking Water Health Advisories				AWQC*		
	Primary MCL	MCL Goal	Secondary MCL	1-Day	10-Day	Longterm	Lifetime	Fish and Water	Fish Only	Water Only*
TCE	5	0	--	--	--	--	--	2.7	80.7	2.8

Note: SDWA = EPA Safe Drinking Water Act.  
MCL = maximum contaminant level.  
MCLG = maximum contaminant level goal.  
AWQC = EPA ambient water quality criteria.  
-- = no value available.

\*Carcinogenic; value represents 10<sup>-6</sup> cancer risk.

\*Value is based on the following formula:

$$\frac{1}{W + F} = \frac{1}{W} + \frac{1}{F}$$

Source: ESE.

Table 3. Air Quality Standards

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	270	135 c	269
STEL	1,080	c	537
CL	1,620 (5 min peak in any 2 hours)	11 (if used as an anesthetic)  137 (all other uses)	--

Note: TWA = time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect.

STEL = short-term exposure limit; 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any time during a workday even if the 8-hour TWA is not exceeded.

CL = ceiling level; unless otherwise specified, the concentration that should not be exceeded at any time during a workday.

c = designates that this chemical is regulated as a potential carcinogen.

Source: ESE.

Table 4. Ambient Water Quality Criteria

LOEL ( $\mu\text{g/L}$ )	Freshwater	Marine
Acute	45,000	2,000
Chronic	21,900	--

Note: -- = not available.

Source: ESE.



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## VINYL CHLORIDE

(CAS No. 75-01-4)

### INTRODUCTION

Approximately 96 percent of the vinyl chloride (also known as chloroethene) produced in the U.S. is used in the production of polyvinyl chloride (PVC) and other vinyl polymers (ORNL, 1989). The remaining 4 percent is used in the synthesis of 1,1,1-trichloroethane. While PVC is used throughout most industries, the plumbing and electrical industries account for the largest portion of the PVC used today. Another large user of PVC is the food industry where PVC is used in plasticized film, bottles, and bottle-cap liners and gaskets; it has been banned from use with alcoholic beverages because of the migration of the vinyl chloride monomer into the alcohol (ORNL, 1989).

Based on its high water solubility of 1,100 mg/L at 20°C and its low soil sorption coefficient ( $K_{oc}$ ) value of 8.2, vinyl chloride is expected to be highly mobile in the soil/groundwater system with little or no retardation in subsurface or sandy soil (ORNL, 1989). With a reported vapor pressure of 2,300 torr at 20°C, vinyl chloride is extremely volatile, and movement through the air-filled pores of the near-surface soils is a major transport pathway (ORNL, 1989). Based on an equilibrium partitioning model, approximately 97 percent of the compound present in the unsaturated near-surface soil at 2°C will be partitioned to the soil-air compartment, with about 2 percent adsorbed to the soil and about 1 percent present in the soil-water compartment (ORNL, 1989). In the saturated deep soil where soil organic carbon and soil air are negligible, about 97 percent is expected to be present in the soil-water compartment, with the remaining 3 percent sorbed to the soil (ORNL, 1989). Soil half-lives of 0.2 and 0.5 day were reported when vinyl chloride was incorporated to a depth of 1 and 10 cm, respectively (ORNL, 1989).

Degradation in the soil is limited; vinyl chloride is resistant to biodegradation in aerobic systems. Following exposure to methanogenic microorganisms in sand, vinyl chloride was 50- and 100-percent degraded within 4 and 11 weeks, respectively, under laboratory conditions; these degradation rates were reduced to 20 and 55 percent, respectively, in the absence of sand (ORNL, 1989). In water, a half-life of 0.805 hour is estimated for a river 1 m deep flowing at 3 m/sec and with a wind velocity of 3 m/sec in the air immediately above the river. In water, no photodegradation was observed after 90 hours, but in the presence of free radicals or of sensitizers that are found in sediments, degradation may occur rapidly (ORNL, 1989). In the atmosphere, vinyl chloride exists primarily in the vapor phase. Any gas-phase vinyl chloride will degrade rapidly as a result of reacting with photochemically produced hydroxyl radicals; the half-life is estimated to be 1.5 days (HSDB, 1991). In the presence of nitrogen oxides, its reactivity is even greater, leading to an estimated half-life of 3 to 7 hours (HSDB, 1991).

## **HUMAN HEALTH EFFECTS**

### **Noncarcinogenic Effects**

EPA has not yet reviewed vinyl chloride with the purpose of deriving oral and inhalation reference doses (RfDs) (IRIS, 1996; EPA, 1995). However, the Agency for Toxic Substances and Disease Registry (ATSDR) does provide a chronic oral minimal risk level (MRL) of 0.0013 mg/kg/day (1989). This MRL is based on a lifetime dietary study in rats by Til *et al.* (1983) in which hepatotoxicity was observed with a NOAEL of 0.13 mg/kg/day and incorporates an uncertainty factor of 100 (10 for animal-to-human extrapolation and 10 for sensitive human subpopulations).

Following acute inhalation exposure, vinyl chloride causes CNS depression (HSDB, 1996). An acute exposure level of 1,000 ppm represents the minimum exposure level at which symptoms, including drowsiness, slight visual disturbances, faltering gait, numbness, and a tingling of the extremities, are reported (HSDB, 1996). No clinical disturbances in humans were reported following a 7-hour exposure to a concentration of 500 ppm (ORNL, 1989).

Little acute exposure data are available regarding experimental animals; the 2-hour LC<sub>50</sub> for mice and rabbits is 113,000 ppm, 150,000 ppm for rats, and 230,000 ppm for guinea pigs (ORNL, 1989). All three species died as a result of narcosis within 30 minutes of exposure to 300,000 ppm; pulmonary edema was noted, but liver and kidney injuries were low (ORNL, 1989).

In addition to the carcinogenic effects of chronic exposure, a decreased number of platelets in the blood, an enlarged spleen, and decreased pulmonary function were reported (ORNL, 1989). Another less frequent effect in humans is a condition known as acroosteolysis, a disease of the hand identified with workers in the vinyl chloride industry. In this disease, growths are found on the hand, the fingers swell and shorten to become club-like, and the individual develops Raynaud's phenomenon, which is a vasomotor disturbance often characterized by acute pain in the fingers that is aggravated by cold (HSDB, 1996). Other long-term effects include hepatic damage as a result of interference with essential pathways, potentially leading to cytotoxic (necrosis or steatosis) and/or cholestatic (biliary stasis) injuries (HSDB, 1996).

### **Carcinogenicity**

Carcinogenic slope factors (CSFs) and supporting information are summarized in Table 1. Having reviewed the carcinogenicity of vinyl chloride, EPA has classified it as a group A (known human) carcinogen by both the inhalation and ingestion routes (EPA, 1995). This classification indicates that sufficient evidence exists of carcinogenicity in humans. An oral CSF of 1.9 (mg/kg/day)<sup>-1</sup> has been derived from a study in which rats exposed to dietary levels of 10 to 50 mg/kg evidenced lung carcinomas (EPA, 1995). An inhalation CSF of

0.3 (mg/kg/day)<sup>1</sup> was derived from a 1-year study in which experimental animals, including several rat strains, were exposed 5 days/week for 1 year to airborne vinyl chloride concentrations that ranged from 1 to 30,000 ppm and to oral doses of 0.03 to 50 mg/kg/day (USAF, 1990; EPA, 1995). The primary effect following inhalation exposure was the formation of liver angiosarcomas, although a wide range of neoplasms were also identified in the kidneys, brain, skin, and the zymbal gland (ORNL, 1989).

Within a group of humans who worked for at least a year in positions involving probable exposure to vinyl chloride, a significant excess of malignant neoplasms of the brain and other areas of the CNS was reported (HSDB, 1996). While hepatic carcinomas have also been associated with exposure to vinyl chloride, the evidence of respiratory tract and digestive tract carcinomas is inconclusive but suggests that vinyl chloride is the causative agent (HSDB, 1996). Carcinogenic effects have also been observed in human fetuses following maternal exposure (ORNL, 1989). In mice and rats, air concentrations as low as 50 ppm have led to liver angiosarcomas as well as other forms of cancer (HSDB, 1996).

With respect to the listed CSFs, EPA (1995) states the following:

"The most recently reviewed quantitative toxicity values listed here (Table 1) appear in EPA documents published in 1984 and 1985. Use of the values on an interim basis was validated by the Carcinogen Risk Assessment Verification Endeavor (CRAVE) (04/05/90). The Agency is aware that these values do not incorporate considerable information that is now available. The Office of Health and Environmental Assessment's position is that these toxicity values do not reflect state-of-the-art science for vinyl chloride. EPA now has individual animal data, not available when the oral unit risk was calculated, that may influence this value. Additional information that may be factored into a revised quantitative toxicity value includes data on increased sensitivity observed in young animals and data on metabolism/ pharmacokinetics. A unit risk for air that considers information on young age exposure increases the risk (i.e., lowers the risk-specific dose) by at least 3-fold. The consideration of metabolism/ pharmacokinetics will further increase the risk. One unpublished physiologically-based pharmacokinetic model prediction results in a 100-fold increased risk."

### **Mutagenicity**

Chromosomal aberrations have been reported in workers occupationally exposed to vinyl chloride, with the most significant abnormalities associated with the highest exposures (HSDB, 1996; ORNL, 1989). Exposures to concentrations below 15 ppm are not expected to result in aberrations (ORNL, 1989).

No mutagenic effects were observed in male mice exposed for 5 days to levels as high as 30,000 ppm. Cells evidenced some mutations (HSDB, 1996) when incubated with liver supernatant from phenobarbital-pretreated rats, which acts as an activator. Mutations were

observed in several *Salmonella* strains and other bacteria, including *Escherichia coli* strains (ORNL, 1989). It was also mutagenic in the recessive lethal test using *Drosophila melanogaster* but not in tests of translocations or sex-chromosome loss.

### **Teratogenicity/Reproductive Effects**

While an increased number of birth defects, including CNS defects, deformities of the upper alimentary and genital tracts, and clubfoot, are associated with exposure to vinyl chloride, the evidence is still unable to show a definitive cause-and-effect relationship (ORNL, 1989; HSDB, 1996). In experimental animals, female mice, rats, and rabbits exposed to levels as high as 2,500 ppm during gestation did not evidence gross teratogenic effects; however, an increase occurred in minor skeletal abnormalities at 500 ppm and higher levels (ORNL, 1989). In a Russian study, pregnant rats exposed continuously to a mean daily concentration of 6.15 mg/m<sup>3</sup> (2.40 ppm) during gestation evidenced embryotoxic and teratogenic effects as manifested by elevated total embryonal mortality, lowered fetal weight, and the induction of external and internal anomalies in fetal development (HSDB, 1996). A value of 10 mg/m<sup>3</sup> (3.9 ppm) was determined to be the threshold value.

Ungvary *et al.* (1978) exposed rats to 1500 ppm vinyl chloride during pregnancy and observed increased fetal mortality but no malformations. Salnikova and Kitsovskaya (1980) exposed Wistar rats to 4.8 mg/m<sup>3</sup> vinyl chloride during the entire gestation by inhalation. An alteration of blood vessel permeability, nervous system functional disturbance, and other abnormalities in offspring were found. A dose of 35.3 mg/m<sup>3</sup> produced a slight embryotoxic effect.

## **ECOTOXICITY**

### **Aquatic Organisms**

Information concerning toxicity of vinyl chloride to aquatic organisms is sparse. When bacterial populations were exposed to levels as high as 900,000 µg/L, no effect was reported, indicating that vinyl chloride is not toxic to bacteria at that concentration (EPA, 1980).

### **Terrestrial Organisms**

No information was identified in the available literature regarding the toxicity of vinyl chloride to vegetation, livestock, or terrestrial wildlife.

## **STANDARDS AND CRITERIA**

### **Human Receptors**

A summary of drinking water standards and criteria is presented as Table 2. Due to the ranking of vinyl chloride as a Group A human carcinogen, EPA has set a nonenforceable Maximum Contaminant Level Goal (MCLG) for drinking water of zero µg/L and a Maximum Contaminant Level (MCL) of 2 µg/L, which is enforceable for public water supplies. Also due to its

carcinogenic ranking, the EPA ambient water quality criterion (AWQC) for the protection of human health should be zero  $\mu\text{g/L}$ . However, zero may not be attainable with present technology; therefore, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 20 to 0.2  $\mu\text{g/L}$  for consumption of contaminated drinking water and aquatic organisms (IRIS, 1996). For consumption of aquatic organisms only, the recommended AWQC for the  $10^{-5}$  to the  $10^{-7}$  risk levels range from 525 to 5.25  $\mu\text{g/L}$ , respectively (IRIS, 1996). These AWQC would yield values for human consumption of water alone (W) of 20, 2, and 0.2  $\mu\text{g/L}$  for  $10^{-5}$ ,  $10^{-6}$ , and  $10^{-7}$  risks, respectively, based on the following equation:

$$\frac{1}{W+F} = \frac{1}{W} + \frac{1}{F}$$

Although vinyl chloride has been designated as a hazardous air pollutant under Section 112 of the Clean Air Act (40 CFR 61.01; (7/1/88), no national ambient air quality standards (NAAQS) have been developed for this chemical. However, the Occupational Safety and Health Administration (OSHA) has promulgated enforceable permissible exposure limits (PELs) for worker exposure (NIOSH, 1996). In addition, the National Institute of Occupational Safety and Health (NIOSH) and the American Conference of Governmental Industrial Hygienists (ACGIH) have developed nonenforceable recommended exposure levels (RELs) and threshold limit values (TLVs), respectively (NIOSH, 1996; ACGIH, 1995). These values are presented in Table 3.

#### **Ecological Receptors**

No AWQCs have been developed for the protection of freshwater or marine organisms against exposure to vinyl chloride, and the lowest levels observed to have an effect (LOELs) on aquatic species have not been determined (EPA, 1987).

Table 1. Carcinogenic Slope Factors and Potential Carcinogenic Effects

Chemical	Carcinogenic Slope Factor (CSF) (mg/kg/day) <sup>-1</sup>	Weight-of-Evidence Classification	Type or Site of Cancer	CSF Basis/CSF Source
Oral	1.9	A	Liver, Lung	EPA, 1995
Inhalation	0.3 <sup>a</sup>	A	Liver	EPA, 1995

Note: A = known human carcinogen (adequate evidence of carcinogenicity in human epidemiological studies).

<sup>a</sup>Inhalation CSF based on an inhalation unit risk of  $8.4 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$  (EPA, 1995) and assumes that a healthy 70-kilogram adult inhales 20 m<sup>3</sup>/day of air.

Source: ESE.



Table 2. Human Regulatory Criteria (µg/L)

Compound	SDWA			Drinking Water Health Advisories				AWQC*		
	Primary MCL	MCL Goal	Secondary MCL	1-Day	10-Day	Longterm	Lifetime	Fish and Water	Fish Only	Water Only*
Vinyl chloride	2	0	--	--	--	--	--	2	525	2

Note: SDWA = EPA Safe Drinking Water Act.  
MCL = maximum contaminant level.  
MCLG = maximum contaminant level goal.  
AWQC = EPA ambient water quality criteria.  
-- = no value available.

\* Carcinogenic; value represents 10<sup>-6</sup> cancer risk.

° Value is based on the following formula:

$$\frac{1}{W + F} = \frac{1}{W} + \frac{1}{F}$$

Source: ESE.

Table 3. Air Quality Standards

Standard (mg/m <sup>3</sup> )	OSHA PEL	NIOSH REL	ACGIH TLV
TWA	2.6 c	c	13 c
STEL	--	--	--
CL	13 (15 min.)	--	--

Note: TWA = time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be exposed on a daily basis without adverse effect.

STEL = short-term exposure limit; 15-minute (unless otherwise specified) TWA exposure that should not be exceeded at any time during a workday even if the 8-hour TWA is not exceeded.

CL = ceiling level; unless otherwise specified, the concentration that should not be exceeded at any time during a workday.

c = designates that this chemical is regulated as a potential carcinogen.

Source: ESE.

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**Appendix N**  
**Human Risks**

Area 1; Current Adult Worker; Chronic

ANALYTE (WOEs: Dermal Oral Inhalation)	MEDIUM					GRAND TOTAL
	IA		Soil			
	PATHWAY	TOTAL	PATHWAY		TOTAL	
	Inhalation		Dermal	Oral		
Aldrin (B2 B2 B2 )			5.0E-09	2.1E-10	5.2E-09	5.2E-09
BHC, gamma- (Lindane) (B2/C B2/C B2/C)			3.0E-10	1.2E-11	3.2E-10	3.2E-10
Benz(a)anthracene (B2 B2 B2 )			2.1E-08	8.5E-10	2.1E-08	2.1E-08
Benzo(a)pyrene (B2 B2 B2 )			1.3E-07	5.4E-09	1.4E-07	1.4E-07
Benzo(b)fluoranthene (B2 B2 B2 )			2.0E-08	8.3E-10	2.1E-08	2.1E-08
Benzo(k)fluoranthene (B2 B2 B2 )			9.4E-10	3.9E-11	9.8E-10	9.8E-10
Bromodichloromethane (B2 B2 B2 )						
Carbon tetrachloride (B2 B2 B2 )	1.7E-06	1.7E-06				1.7E-06
Chlordane, alpha- (B2 B2 B2 )			2.6E-09	1.1E-10	2.7E-09	2.7E-09
Chlordane, gamma- (B2 B2 B2 )			3.2E-09	1.3E-10	3.3E-09	3.3E-09
Chloroform (B2 B2 B2 )	2.1E-07	2.1E-07				2.1E-07
Chrysene (B2 B2 B2 )			2.1E-10	8.6E-12	2.2E-10	2.2E-10
Dichloroethane, 1,1- (C C C )						
Dichloroethene, 1,1- (C C C )	1.5E-05	1.5E-05				1.5E-05
Dinitrotoluene, 2,4- (B2 B2 B2 )			7.1E-08	2.9E-09	7.4E-08	7.4E-08
Indeno(1,2,3-cd)pyrene (B2 B2 B2 )			1.3E-08	5.3E-10	1.3E-08	1.3E-08
Methylene chloride (B2 B2 B2 )	5.3E-10	5.3E-10				5.3E-10
Nitrosodi-N-propylamine, N- (B2 B2 B2 )			3.6E-06	1.5E-07	3.7E-06	3.7E-06
Tetrachloroethene (B2 B2 B2 )	1.1E-07	1.1E-07				1.1E-07
Trichloroethene (B2 B2 B2 )	1.1E-06	1.1E-06				1.1E-06
Vinyl chloride (A A A )	1.8E-05	1.8E-05				1.8E-05
TOTAL	3.5E-05	3.5E-05	3.8E-06	1.6E-07	4.0E-06	3.9E-05

Area 1; Future Adult Worker; Chronic

ANALYTE (WOEs: Dermal Oral Inhalation)	MEDIUM						GRAND TOTAL
	IA		Soil				
	PATHWAY	TOTAL	PATHWAY		TOTAL		
	Inhalation		Dermal	Oral			
Aldrin (B2 B2 B2 )			2.5E-08	4.2E-09	2.9E-08	2.9E-08	
BHC, gamma- (Lindane) (B2/C B2/C B2/C)			1.5E-09	2.5E-10	1.8E-09	1.8E-09	
Benz(a)anthracene (B2 B2 B2 )			1.0E-07	1.7E-08	1.2E-07	1.2E-07	
Benzo(a)pyrene (B2 B2 B2 )			6.6E-07	1.1E-07	7.7E-07	7.7E-07	
Benzo(b)fluoranthene (B2 B2 B2 )			1.0E-07	1.7E-08	1.2E-07	1.2E-07	
Benzo(k)fluoranthene (B2 B2 B2 )			4.7E-09	7.8E-10	5.5E-09	5.5E-09	
Bromodichloromethane (B2 B2 B2 )							
Carbon tetrachloride (B2 B2 B2 )	4.4E-05	4.4E-05				4.4E-05	
Chlordane, alpha- (B2 B2 B2 )			1.3E-08	2.2E-09	1.5E-08	1.5E-08	
Chlordane, gamma- (B2 B2 B2 )			1.6E-08	2.6E-09	1.9E-08	1.9E-08	
Chloroform (B2 B2 B2 )	5.4E-06	5.4E-06				5.4E-06	
Chrysene (B2 B2 B2 )			1.0E-09	1.7E-10	1.2E-09	1.2E-09	
Dichloroethane, 1,1- (C C C )							
Dichloroethene, 1,1- (C C C )	3.7E-04	3.7E-04				3.7E-04	
Dinitrotoluene, 2,4- (B2 B2 B2 )			3.6E-07	5.9E-08	4.2E-07	4.2E-07	
Indeno(1,2,3-cd)pyrene (B2 B2 B2 )			6.4E-08	1.1E-08	7.5E-08	7.5E-08	
Methylene chloride (B2 B2 B2 )	1.3E-08	1.3E-08				1.3E-08	
Nitrosodi-N-propylamine, N- (B2 B2 B2 )			1.8E-05	2.9E-06	2.1E-05	2.1E-05	
Tetrachloroethene (B2 B2 B2 )	2.6E-06	2.6E-06				2.6E-06	
Trichloroethene (B2 B2 B2 )	2.8E-05	2.8E-05				2.8E-05	
Vinyl chloride (A A A )	4.4E-04	4.4E-04				4.4E-04	
TOTAL	8.8E-04	8.8E-04	1.9E-05	3.2E-06	2.2E-05	9.1E-04	

Zone 1; Lifetime Resident

ANALYTE (WOEs: Dermal Oral Inhalation)	MEDIUM						GRAND TOTAL
	IA		Soil				
	PATHWAY	TOTAL	PATHWAY		TOTAL		
	Inhalation		Dermal	Oral			
Aldrin (B2 B2 B2 )			5.4E-08	3.7E-08	9.1E-08	9.1E-08	
BHC, gamma- (Lindane) (B2/C B2/C B2/C)			3.2E-09	2.2E-09	5.5E-09	5.5E-09	
Benz(a)anthracene (B2 B2 B2 )			2.2E-07	1.5E-07	3.7E-07	3.7E-07	
Benzo(a)pyrene (B2 B2 B2 )			1.4E-06	9.7E-07	2.4E-06	2.4E-06	
Benzo(b)fluoranthene (B2 B2 B2 )			2.1E-07	1.5E-07	3.6E-07	3.6E-07	
Benzo(k)fluoranthene (B2 B2 B2 )			1.0E-08	7.0E-09	1.7E-08	1.7E-08	
Bromodichloromethane (B2 B2 B2 )							
Carbon tetrachloride (B2 B2 B2 )	6.6E-05	6.6E-05				6.6E-05	
Chlordane, alpha- (B2 B2 B2 )			2.8E-08	1.9E-08	4.7E-08	4.7E-08	
Chlordane, gamma- (B2 B2 B2 )			3.4E-08	2.4E-08	5.8E-08	5.8E-08	
Chloroform (B2 B2 B2 )	8.1E-06	8.1E-06				8.1E-06	
Chrysene (B2 B2 B2 )			2.2E-09	1.5E-09	3.8E-09	3.8E-09	
Dichloroethane, 1,1- (C C C )							
Dichloroethene, 1,1- (C C C )	5.5E-04	5.5E-04				5.5E-04	
Dinitrotoluene, 2,4- (B2 B2 B2 )			7.6E-07	5.3E-07	1.3E-06	1.3E-06	
Indeno(1,2,3-cd)pyrene (B2 B2 B2 )			1.4E-07	9.5E-08	2.3E-07	2.3E-07	
Methylene chloride (B2 B2 B2 )	2.0E-08	2.0E-08				2.0E-08	
Nitrosodi-N-propylamine, N- (B2 B2 B2 )			3.8E-05	2.6E-05	6.4E-05	6.4E-05	
Tetrachloroethene (B2 B2 B2 )	4.0E-06	4.0E-06				4.0E-06	
Trichloroethene (B2 B2 B2 )	4.2E-05	4.2E-05				4.2E-05	
Vinyl chloride (A A A )	6.6E-04	6.6E-04				6.6E-04	
TOTAL	1.3E-03	1.3E-03	4.1E-05	2.8E-05	6.9E-05	1.4E-03	



QDRUM...ES  
NONCARCINOGENIC HAZARD INDICES

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Area 1; Current Adult Worker; Chronic

ANALYTE	MEDIUM					GRAND TOTAL
	IA		Soil			
	PATHWAY	TOTAL	PATHWAY		TOTAL	
	Inhalation		Dermal	Oral		
Acetone						
Aldrin			2.8E-05	1.1E-06	2.9E-05	2.9E-05
BHC, gamma- (Lindane)			2.2E-06	9.0E-08	2.3E-06	2.3E-06
Benz(a)anthracene			2.6E-06	1.1E-07	2.7E-06	2.7E-06
Benzo(a)pyrene			1.7E-06	6.9E-08	1.7E-06	1.7E-06
Benzo(b)fluoranthene			2.6E-06	1.1E-07	2.7E-06	2.7E-06
Benzo(k)fluoranthene			1.2E-06	5.0E-08	1.3E-06	1.3E-06
Bromodichloromethane						
Carbon tetrachloride	1.6E-01	1.6E-01				1.6E-01
Chlordane, alpha-			9.4E-05	3.9E-06	9.8E-05	9.8E-05
Chlordane, gamma-			1.2E-04	4.7E-06	1.2E-04	1.2E-04
Chloroform						
Chrysene			2.7E-06	1.1E-07	2.8E-06	2.8E-06
Dichloroethane, 1,1-	7.9E-04	7.9E-04				7.9E-04
Dichloroethene, 1,1-						
Dichloroethenes, 1,2-, total						
Dinitrotoluene, 2,4-			1.5E-04	6.1E-06	1.5E-04	1.5E-04
Indeno(1,2,3-cd)pyrene			1.6E-06	6.8E-08	1.7E-06	1.7E-06
Methylene chloride	1.1E-06	1.1E-06				1.1E-06
Nitrosodi-N-propylamine, N-			1.5E-04	6.2E-06	1.6E-04	1.6E-04
Tetrachloroethene						
Thallium			9.3E-03	3.8E-03	1.3E-02	1.3E-02
Trichloroethane, 1,1,1-	2.2E-03	2.2E-03				2.2E-03
Trichloroethene						
Vinyl chloride						
TOTAL	1.7E-01	1.7E-01	9.8E-03	3.9E-03	1.4E-02	1.8E-01

QDRUM ARES  
NONCARCINOGENIC HAZARD INDICES

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Area 1; Future Adult Worker; Chronic

ANALYTE	MEDIUM					GRAND TOTAL
	IA		Soil			
	PATHWAY	TOTAL	PATHWAY		TOTAL	
	Inhalation		Dermal	Oral		
Acetone						
Aldrin			1.4E-04	2.3E-05	1.6E-04	1.6E-04
BHC, gamma- (Lindane)			1.1E-05	1.8E-06	1.3E-05	1.3E-05
Benz(a)anthracene			1.3E-05	2.2E-06	1.5E-05	1.5E-05
Benzo(a)pyrene			8.4E-06	1.4E-06	9.8E-06	9.8E-06
Benzo(b)fluoranthene			1.3E-05	2.1E-06	1.5E-05	1.5E-05
Benzo(k)fluoranthene			6.0E-06	9.9E-07	7.0E-06	7.0E-06
Bromodichloromethane						
Carbon tetrachloride	4.1E+00	4.1E+00				4.1E+00
Chlordane, alpha-			4.7E-04	7.8E-05	5.5E-04	5.5E-04
Chlordane, gamma-			5.8E-04	9.5E-05	6.7E-04	6.7E-04
Chloroform						
Chrysene			1.3E-05	2.2E-06	1.6E-05	1.6E-05
Dichloroethane, 1,1-	2.0E-02	2.0E-02				2.0E-02
Dichloroethene, 1,1-						
Dichloroethenes, 1,2-, total						
Dinitrotoluene, 2,4-			7.4E-04	1.2E-04	8.6E-04	8.6E-04
Indeno(1,2,3-cd)pyrene			8.2E-06	1.4E-06	9.6E-06	9.6E-06
Methylene chloride	2.7E-05	2.7E-05				2.7E-05
Nitrosodi-N-propylamine, N-			7.5E-04	1.2E-04	8.7E-04	8.7E-04
Tetrachloroethene						
Thallium			4.6E-02	7.7E-02	1.2E-01	1.2E-01
Trichloroethane, 1,1,1-	5.6E-02	5.6E-02				5.6E-02
Trichloroethene						
Vinyl chloride						
TOTAL	4.2E+00	4.2E+00	4.9E-02	7.7E-02	1.3E-01	4.3E+00

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NONCARCINOGENIC HAZARD INDICES

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Area 1; Future Adult Resident; Chronic

ANALYTE	MEDIUM					GRAND TOTAL
	IA		Soil			
	PATHWAY	TOTAL	PATHWAY		TOTAL	
	Inhalation		Dermal	Oral		
Acetone						
Aldrin			2.2E-04	6.4E-05	2.9E-04	2.9E-04
BHC, gamma- (Lindane)			1.7E-05	5.0E-06	2.2E-05	2.2E-05
Benz(a)anthracene			2.1E-05	6.1E-06	2.7E-05	2.7E-05
Benzo(a)pyrene			1.3E-05	3.9E-06	1.7E-05	1.7E-05
Benzo(b)fluoranthene			2.1E-05	5.9E-06	2.7E-05	2.7E-05
Benzo(k)fluoranthene			9.7E-06	2.8E-06	1.2E-05	1.2E-05
Bromodichloromethane						
Carbon tetrachloride	4.3E+00	4.3E+00				4.3E+00
Chlordane, alpha-			7.5E-04	2.2E-04	9.7E-04	9.7E-04
Chlordane, gamma-			9.2E-04	2.7E-04	1.2E-03	1.2E-03
Chloroform						
Chrysene			2.1E-05	6.2E-06	2.8E-05	2.8E-05
Dichloroethane, 1,1-	2.1E-02	2.1E-02				2.1E-02
Dichloroethene, 1,1-						
Dichloroethenes, 1,2-, total						
Dinitrotoluene, 2,4-			1.2E-03	3.4E-04	1.5E-03	1.5E-03
Indeno(1,2,3-cd)pyrene			1.3E-05	3.8E-06	1.7E-05	1.7E-05
Methylene chloride	2.8E-05	2.8E-05				2.8E-05
Nitrosodi-N-propylamine, N-			1.2E-03	3.5E-04	1.6E-03	1.6E-03
Tetrachloroethene						
Thallium			7.4E-02	2.1E-01	2.9E-01	2.9E-01
Trichloroethane, 1,1,1-	5.8E-02	5.8E-02				5.8E-02
Trichloroethene						
Vinyl chloride						
TOTAL	4.4E+00	4.4E+00	7.9E-02	2.2E-01	2.9E-01	4.7E+00

QDRUM ARES  
NONCARCINOGENIC HAZARD INDICES

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Area 1; Future Child Resident; Chronic

ANALYTE	MEDIUM					GRAND TOTAL
	IA		Soil			
	PATHWAY	TOTAL	PATHWAY		TOTAL	
	Inhalation		Dermal	Oral		
Acetone						
Aldrin			6.9E-04	6.0E-04	1.3E-03	1.3E-03
BHC, gamma- (Lindane)			5.4E-05	4.7E-05	1.0E-04	1.0E-04
Benz(a)anthracene			6.6E-05	5.7E-05	1.2E-04	1.2E-04
Benzo(a)pyrene			4.2E-05	3.6E-05	7.8E-05	7.8E-05
Benzo(b)fluoranthene			6.4E-05	5.5E-05	1.2E-04	1.2E-04
Benzo(k)fluoranthene			3.0E-05	2.6E-05	5.6E-05	5.6E-05
Bromodichloromethane						
Carbon tetrachloride	2.1E+01	2.1E+01				2.1E+01
Chlordane, alpha-			2.3E-03	2.0E-03	4.4E-03	4.4E-03
Chlordane, gamma-			2.9E-03	2.5E-03	5.3E-03	5.3E-03
Chloroform						
Chrysene			6.6E-05	5.8E-05	1.2E-04	1.2E-04
Dichloroethane, 1,1-	1.0E-01	1.0E-01				1.0E-01
Dichloroethene, 1,1-						
Dichloroethenes, 1,2-, total						
Dinitrotoluene, 2,4-			3.7E-03	3.2E-03	6.8E-03	6.8E-03
Indeno(1,2,3-cd)pyrene			4.1E-05	3.5E-05	7.6E-05	7.6E-05
Methylene chloride	1.4E-04	1.4E-04				1.4E-04
Nitrosodi-N-propylamine, N-			3.7E-03	3.2E-03	7.0E-03	7.0E-03
Tetrachloroethene						
Thallium			2.3E-01	2.0E+00	2.2E+00	2.2E+00
Trichloroethane, 1,1,1-	2.9E-01	2.9E-01				2.9E-01
Trichloroethene						
Vinyl chloride						
TOTAL	2.2E+01	2.2E+01	2.4E-01	2.0E+00	2.3E+00	2.4E+01

**APPENDIX O**  
**POTENTIAL ARARs**

### Determination of ARARs

Determination of the extent to which federal, state, or local public health and environmental standards are applicable or relevant and appropriate to a site is required by the NCP.

Applicable requirements are those federal and state requirements that would be legally applicable to the response action if that action were not taken pursuant to Sections 104 or 106 of CERCLA. Relevant and appropriate requirements are those federal or state requirements that, while not applicable, are designed to apply to problems sufficiently similar to those encountered at CERCLA sites that their application is appropriate. Relevant and appropriate requirements are intended to have the same weight as applicable requirements. EPA has also indicated that other "to be considered" federal and state criteria, advisories, and guidelines be considered during the development of alternatives. Examples of such criteria include EPA Drinking Water-Health Advisories, VDEQ guidelines for the disposal of petroleum-contaminated soil, carcinogenic potency factors, and reference doses.

Three categories for ARARs are as follows:

- **Contaminant-Specific.** These ARARs may be actual concentration-based cleanup levels or provide the basis for calculating such levels. At the QADSY site, groundwater and surface soil were identified as being contaminated. VDEQ Water Quality Standards for groundwater are considered ARARs. However, when no chemical-specific groundwater standards are available, VDEQ Water Quality Standards for surface water (protection of human health, non-public water supplies) are considered ARARs because VDOH groundwater restrictions are in place for the aquifer, no known drinking water wells are located in the aquifer in the area, the aquifer is not considered potable, and the groundwater appears to be discharging to surface water (non-public water supply). VDEQ guidelines for the disposal of petroleum-contaminated soil are considered ARARs for the surface soil.
- **Location-Specific.** These ARARs are based on the site's location and impact on human health and the environment. These ARARs place restrictions on the concentration of hazardous substances and conduct of activities due to the site's specific location. Examples of special locations include floodplains, wetlands, historic places, and sensitive ecosystems or habitats.
- **Action-Specific.** These ARARs are technology- or activity-based requirements on actions taken with respect to hazardous wastes. These ARARs are determined by the particular remedial activities selected to accomplish a remedy.

### Chemical-Specific ARARs

Table O-1 lists all contaminants exceeding enforceable federal and state ARARs for groundwater and surface soil.

The chemical-specific ARARs were selected on the following grounds:

- The impacted aquifer is not used for drinking water in the vicinity of the site
- No drinking water wells could potentially be affected by site contamination
- Groundwater discharges to a non-public water supply surface water body

Resulting from a Restoration Advisory Board (RAB) Meeting on 18 December 1992, VDEQ Waste Management department commented that "MCLs for organics are also valid to use in assessing groundwater quality and the risks to human health that the site might pose." The comment referred to a concern that the Yorktown aquifer could have been impacted by site contamination and suggested consulting with Gene Siudyla of the VDEQ's Tidewater office.

Additional data were collected from the site and analyzed following the TRC meeting, and a discussion with Mr. Siudyla occurred on 14 April 1993; the following conclusions resulted. In general, the Yorktown does not exhibit the productivity necessary for drinking water wells in the vicinity of the site. In the Norfolk area, the materials are commonly silty sands, sandy silts, shell fragments, and clays with low permeabilities and low hydraulic conductivities. The Yorktown aquifer is only used for industrial purposes and lawn watering in the general vicinity, not for drinking water.

The lowermost leading edge of the contaminant plume was detected during the hydropunch investigation and appears to attenuate around 65 feet below the surface. Groundwater modeling at that level indicates that the aquifer discharges to the Elizabeth River and Willoughby Bay, and groundwater flows in the direction of those surface water bodies. Additionally, no known drinking water wells are located downgradient of the site (i.e., in the Elizabeth River or Willoughby Bay); therefore, no drinking water wells should be impacted by site contamination. Neither Elizabeth River or Willoughby Bay is used for drinking water because the surface water bodies are brackish.

Because groundwater discharges to the local surface water, the impact of groundwater quality on surface water is a valid consideration at the site. As a result, the risk-based RGOs are used as ARARs to assess the risks to human health and the environment.

MCLs are not considered valid as ARARs mainly because the aquifer:

- Yorktown becomes brackish with depth adjacent to surface water bodies (e.g., Elizabeth River and Willoughby Bay) and is not suitable for consumption;
- City of Norfolk prohibits the use of the water table aquifer for potable purposes by law; and

- Columbia and Yorktown aquifers comprise the water table aquifer because no confining layer exists at the site.

RGOs calculated from the RA are relevant and appropriate because of the following:

- No VDEQ groundwater standards exist for TCE and PCE.
- The groundwater model determines groundwater discharges into the Elizabeth River, hence no downgradient receptors.

The QADSY was created by a fill operation as a disposal area for dredged materials excavated from the James River, Elizabeth River, and/or Willoughby Bay in the early 1950's. The dredged material has been recognized to contain elevated levels of IOC contamination. There are no records where the dredged material came from or may be from numerous sources.

Background soil data was collected at a upgradient located adjacent to Bousch Creek. Background soil data indicated IOC data was within a order of magnitude from the highest concentration measured during the RI. The IOC impacted soil will be too complex to delineate because of the unknown source or sources of the dredged material.

No action for soil is relevant and appropriate at the QADSY because of the following .

- IOCs contamination appears to be inherited from the dredged material.
- The QADSY is not conducive to an ecological environment because the site is in a highly industrial area which is mostly a paved parking lot.
- The future plans of the unpaved QADSY area will be paved and subsequently terminating this ecologic risk pathway.

#### Location-Specific ARARs

The QADSY site currently has no potential location-specific ARARs. The site is not:

- A wetland
- Within a floodplain
- Within a coastal zone as designated by the Commonwealth of Virginia
- Within an area affecting national wild, scenic, or recreational rivers
- Within environmentally significant agricultural lands
- A critical habitat area upon which federally designated endangered or threatened species depend
- On property included in or eligible for the National Register of Historic Places



Accordingly, Executive Orders 11988 and 11990, the Coastal Zone Management Act, the Wild and Scenic Rivers Act, the Farmland Protection Policy Act, the Endangered Species Act, and National Historic Preservation Act are not considered ARARs for the QADSY.

#### Action-Specific ARARs

These ARARs represent standards that limit or restrict specific activities associated with the implementation of a given remedial alternative. Table O-2 lists the ARARs applicable to a particular action and the requirements associated with the ARARs, and Table O-3 lists the to be considered requirements.

**Table O-1. Groundwater and Surface Soil Contaminants Exceeding Standards and Guidelines**

Indicator Chemical	Maximum Concentration			RGOs	
	Hydropunch (µg/l)	Groundwater (µg/l)	Surface Soil (mg/kg)	Groundwater (µg/l)	Soil (mg/kg)
Tetrachloroethene (PCE)	452	4800	BRGOs	59.6	BRGOs
Trichloroethene (TCE)	1371	560	BRGOs	48.9	BRGOs
1,1-Dichloroethene (DCE)	NA	140	BRGOs	0.38	BRGOs
Carbon Tetrachloride	NA	120	BRGOs	2.7	BRGOs
Vinyl Chloride	NA	34	BRGOs	0.077	BRGOs
Chloroform	NA	4700	BRGOs	11.1	BRGOs

NA = Not Analyzed  
BRGOs = Below RGOs

TABLE O-2

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)  
Q-AREA DRUM STORAGE YARD

Citation	Requirement	ARAR Determination	Comments
<b>Federal/Contaminant-Specific</b>			
Safe Drinking Water Act (42 USC 300(f)) a. Maximum Contaminant Levels (MCLs) 40 CFR 141.11-141.16 b. Maximum Contaminant Level Goals (MCLGs) 40 CFR 141.50-141.51	Standards for protection of drinking water sources serving at least 25 persons. MCLs consider health factors, as well as economic and technical feasibility of removing a contaminant; MCLGs do not consider the technical feasibility of contaminant removal. For a given contaminant, the more stringent of MCLs or MCLGs is applicable unless the MCLG is zero, in which case the MCL applies.	Not applicable or relevant and appropriate because the water table aquifer is not used for potable consumption.	MCLs are not ARARs due to the following: 1) City of Norfolk prohibits the use of the water table aquifer; 2) The Columbia and Yorktown aquifers comprise the water table aquifer because no confining layer exists at the site; and 3) Yorktown becomes brackish with depth adjacent to surface water bodies (e.g., Elizabeth River and Willoughby bay) and is not suitable for consumption.
<b>Federal/Location-Specific</b>			
The Endangered Species Act of 1973 (16 USC 1531) (40 CFR Part 502)	Requires Action to conserve endangered and threatened species and their critical habitats.	Not applicable or relevant and appropriate.	Peregrine falcons have been seen on base; however, they been seen over one mile from the QADSY. There are no wetlands within 0.25 mile from the site.
Coastal Zone Management Act (16 USC 3501)	Conduct activities in a manner consistent with approved State management programs.	Not applicable or relevant and appropriate.	QADSY is not within a coastal zone designated by the Commonwealth of Virginia
National Historic Preservation Act (32 CFR Parts 229 and 229.4; 43 CFR Parts 107 and 171.1-5)	Develops procedures for the protection of archaeological resources.	Not applicable or relevant and appropriate.	QADSY is not on property included in or eligible for the National Register of Historic Places. Additionally, Sewalls point was created by a fill operation from dredge materials from Willoughby Bay.
Executive Order 11988 (Related to Floodplain Management)	Regulates activities located in a floodplain must comply with this Executive Order. Federal activities in floodplains must reduce the risk of flood loss, minimize the impact of floods on human safety, health and welfare, and preserve the natural environment served by floodplains.	Not applicable or relevant and appropriate.	QADSY is not within a floodplain
<b>Federal/Action-Specific</b>			
DOT Rules for Hazardous Materials Transport (40 CFR Parts 107 and 171.1-500)	Regulates the transport of hazardous waste materials including packaging, shipping and placarding.	Not applicable or relevant and appropriate	Remedial actions does not include offsite soil disposal.

Citation	Requirement	ARAR Determination	Comments
Resource Conservation and Recovery Act (RCRA) Subtitle C	Regulates the treatment, storage, and disposal of hazardous waste.	Applicable to remedial actions involving treatment, storage, or disposal of hazardous wastes.	Remediation may involve disposal of hazardous wastes
Identification and Listing of Hazardous Waste (40 CFR Part 261)	Regulations concerning determination of whether or not a waste is hazardous based on characteristics or listing.	Applicable in determining waste classification.	Some site contaminants are considered listed wastes.
Treatment, Storage, and Disposal (TSD) of Hazardous Waste (40 CFR Parts 262-265, 266)	Regulates the treatment, storage, and disposal of hazardous waste.	Applicable in the event that wastes on site are classified as hazardous.	Groundwater treatment activities related to hazardous waste will comply with regulations.
Manifest Systems, Recordkeeping, and Reporting (40 CFR Part 264, Subpart E)	Regulates manifest systems related to hazardous waste treatment, storage, and disposal.	Applicable to remedial actions where hazardous waste is generated or transported.	Remedial actions may include off-site disposal or treatment.
Releases from Solid Waste Management Units (40 CFR Part 264, Subpart F)	Regulates releases from solid waste management units.	Not applicable or relevant and appropriate.	Does not meet the definition of A SWMU.
Use and Management of Containers (40 CFR Part 264, Subpart I)	Regulates use and management of containers being stored at all hazardous waste facilities.	Not applicable or relevant and appropriate.	No containerized wastes are onsite. Remedial actions will not generate containerized wastes.
Resource Conservation and Recovery Act (RCRA) Subtitle D	Regulates the treatment, storage, and disposal of solid waste.	Not applicable or relevant and appropriate.	Remediation actions do not include treatment, storage, or disposal of solid waste.
National Emissions Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR Part 61)	Standards promulgated under the Clean Air Act for significant sources of hazardous pollutants, such as vinyl chloride, benzene, trichloroethylene, dichlorobenzene, asbestos, and other hazardous substances. Considered for any source that has the potential to emit 10 tons of any hazardous air pollutant or 25 tons of a combination of hazardous air pollutants per year.	Applicable to potential releases of hazardous pollutants. Remedial actions (e.g. air stripping) may result in releasing hazardous air pollutants. Treatment design will include air emissions control equipment as required to comply with NESHAPs.	Air emissions from the treatment facility will not exceed air emission standards during the remedial design.

Citation	Requirement	ARAR Determination	Comments
<b>State/Contaminant-Specific</b>			
Virginia Waster Quality Standards (VR 680-21-00)	Surface water quality standards based on water use and criteria class of surface water.	Applicable to remedial actions requiring discharge to surface water.	Effluent water from the treatment facility will be below VDEQ surface water standards.
Virginia Groundwater Standard (VR 680-21-04.3)	Established groundwater standards for State Antidegradation policy.	Not applicable or relevant and appropriate.	Groundwater concentrations are below the VDEQ groundwater standards.
Virginia Ambient Air Quality Standards (VAQS) (VR 120-03-01)	Primary and secondary air quality standards for particulate matter, sulfur oxides, carbon monoxide, nitrogen dioxide, and lead.	Applicable for remedial actions requiring discharge to the atmosphere.	Monitoring of air emissions from the treatment technology will comply with VAQS requirements
Virginia Emission Standards for Toxic Pollutants (VR 120-01)	Established acceptable limits for toxic pollutants by applying a 1/40 correction factor to the occupational standard Threshold Limit Value-Ceiling (TLV-Ceiling).	Applicable for remedial actions requiring discharge to the atmosphere.	Remedial design will determine air emissions from the treatment technology will not exceed emission standards.
Virginia Pollution Discharge Elimination System (VPDES (VR 680-14-01) Regulation and Virginia Water Protection Permit Regulations (VR 680-15-01)	Regulated point-source discharges through the VPDES permitting program. Permit requirements include compliance with corresponding water quality standards, establishment of a discharge monitoring system, and completion of regular discharge monitoring records.	Applicable to remedial actions requiring treated water discharge to surface water.	VPDES permit requirements will determine discharge limits of treated water to surface water.
<b>State/Action-Specific</b>			
Virginia Solid Waste Management Regulations (VR 672-20-10)	Regulates the disposal of solid wastes.	Not applicable or relevant and appropriate.	No solid wastes to be removed from the QADSY.
Virginia Hazardous Waste Regulations (VR 72-30-1 and VR 672-10-1, Part VII)	Regulates the transport of hazardous waste materials including packaging, shipping, and placarding.	Applicable to remedial action requiring off-site transportation of hazardous materials.	Remedial action may include off-site disposal treatment.
Virginia Hazardous Waste Management Regulations (VR 672-10-1)	Regulates the treatment, storage, and disposal of hazardous waste.	Applicable to remediation systems involving treatment, storage, or disposal of hazardous wastes.	Remedial action may include treatment, storage, or disposal of hazardous wastes.
Identification and Listing of Hazardous Waste (VR 672-10-1, Part III)	Regulations concerning determination of whether or not a waste is hazardous based on characteristics or listing.	Applicable to determining waste classification.	Some of the contaminants are considered listed wastes.
Manifest Systems, Recordkeeping, and Reporting (VR 672-10-1, Part X, Section 10.4)	Regulates manifest systems related to hazardous waste treatment, storage, and disposal.	Applicable to hazardous wastes is generated or transported during remediation.	Off-site disposal may be included during remedial actions.
Releases from Solid Waste Management Units (VR 672-10, Part X, Section 10.5)	Regulates releases from solid waste management units.	Not applicable or relevant and appropriate.	Does not meet the definition of A SWMU..
Use and Management of Containers (VR 672-10, Part X, Section 10.8)	Regulates use and management of containers being stored at all hazardous waste facilities.	Applicable to containers stored onsite.	Containerized wastes may be generated during remediation.

Citation	Requirement	ARAR Determination	Comments
Virginia Stormwater Management Regulations (VR 215-02-00) and Virginia Erosion and Sediment Control Regulations (VR 625-02-00)	Regulates stormwater management and erosion/ sedimentation control practices that must be followed during land disturbing activities.	Applicable for remedial actions involving land disturbing activities.	Construction activities will comply to the Virginia Storm Water Management Plan.
Virginia Endangered Species Act (Code of Virginia 29.1-563)	Requires action to conserve endangered and threatened species and their critical habitats.	Not applicable or relevant and appropriate.	Peregrine falcons have been seen on base; however, they been seen over one mile from the QADSY. There are no wetlands within 0.25 mile from the site.
Virginia Wetlands Regulations (VR 450-01-0051)	Regulates activities that impact tidal wetlands.	Not applicable or relevant and appropriate.	There are no wetlands within 0.25 mile from the site.
Chesapeake Bay Preservation Area Designation and Management Regulations (VR 173-02-01)	Sets limitations in certain tidal and wetland areas for land-disturbing activities, removal of vegetation, use of impervious cover, E&S control, stormwater management, etc.	Not applicable or relevant and appropriate.	There are no wetlands within 0.25 mile from the site.
Coastal Management Plan - City of Norfolk	Activities within a Coastal Management Zone must be in compliance with local requirements.	Not applicable or relevant and appropriate.	QADSY is not located within a Coastal Management Zone.

TABLE O-3

## TO BE CONSIDERED (TBC) REQUIREMENTS

Citation	Requirement	ARAR Determination	Comments
<b>Federal/Contaminant-Specific</b>			
Reference Doses (RfDs), EPA Office of Research and Development	Presents non-enforceable toxicity data for specific chemicals for use in public health assessments to characterize risks due to exposure to contaminants.	TBC requirement for the public health assessment.	The quantitative risk assessment (RA) evaluated human health risks.
Carcinogenic Potency Factors, EPA Environmental Criteria and Assessment Office; EPA Carcinogen Assessment Group	Presents non-enforceable toxicity data for specific chemicals for use in public health assessments to compute the individual incremental cancer risk resulting from exposure to carcinogens.	TBC requirement for the public health assessment.	The quantitative risk assessment (RA) evaluated human health risks.
Health Advisories, EPA Office of Drinking Water	Non-enforceable guidelines for chemicals that may intermittently be encountered in public water supply systems. Available for short- or long-term exposure for a child and/or adult.	TBC requirement for the public health assessment.	The quantitative risk assessment (RA) evaluated human health risks.
<b>Federal/Location-Specific</b>			
RCRA Subtitle C Landfills (40 CFR Part 264, Subpart N)	Regulates owners and operators of facilities that dispose hazardous wastes in landfills.	TBC to evaluate compliance of off-site landfills.	TBC for remedial actions will not involve disposal at off-site landfills.
Groundwater Protection Strategy	EPA policy to protect groundwater for its highest present or potential beneficial use. The strategy designates three categories of groundwater: Class 1 - Special Ground Waters Class 2 - Current and Potential Sources of Drinking Water and Waters Having Other Beneficial Uses Class 3 - Groundwater Not a Potential Source of Drinking Water and of Limited Beneficial Use	TBC requirement	Groundwater in the water table aquifer consists of the Columbia and Yorktown aquifers at the QADSY and is considered as Class 3.
<b>Federal/Action-Specific</b>			
National Ambient Air Quality Standards (NAAQS) (40 CFR 50)	Standards for the following six criteria pollutants: particulate matter; sulfur dioxide; carbon monoxide; ozone; nitrogen dioxide; and lead. The attainment and maintenance of these standards are required to protect the public health and welfare.	TBC requirements for remedial actions that discharge into to the atmosphere. The treatment system will include equipment to control air emissions to comply with NAAQS.	Remedial actions will include monitoring air emissions from the treatment system with NAAQS requirements.
Control if Air Emissions from Superfund Air Strippers at Superfund Ground Water Sites (OSWER Directive 9355.0-28)	Guidance that establishes criteria as to whether air emission controls are necessary for air strippers. A maximum 3 lbs/hr or 15 lbs/day or 10 tons/yr of VOC emissions is allowable; air pollution controls are recommended for any emissions in excess of these quantities.	TBC requirement	TBC if the remedial action includes air stripping.

Citation	Requirement	ARAR Determination	Comments
<b>State/Contaminant-Specific</b>			
RCRA Subtitle C Landfills (VR 672-10, Part X, Section 10.13)	Regulates owners and operators of facilities that dispose hazardous wastes in landfills.	TBC to evaluate compliance of off-site landfills.	TBC for remedial actions will not involve disposal at off-site landfills.



**APPENDIX P**

**GROUNDWATER  
VOLUME CALCULATIONS**

**Calculation for Water Volume to be Treated at QADSY  
(See Figure 11-1 for dimensions used.)**

- Volume of plume requiring treatment

Elizabeth River Site

QADSY Site

641,119 square feet (sf)  
(depth of plume, as measured in Hydro-  
punch HP-11 and HP-15) approximately  
35 feet

146,014 sf  
(depth of plume, as measured in  
SW-2) approximately 25 feet

= 22,439,165 cubic feet (cf)

= 3,650,350 cf

Total Volume = 22,439,165 cf + 3,650,350 cf = 26,089,515 cf

- Porosity @ 30% (Freeze & Cherry)

Volume of water = 7,826,855 cf

- Estimate 5 volumes to reduce levels to within remedial action goals

≈ 39,000,000 cf

@ 7.48 gallons/ft<sup>3</sup>

= 291,720,000 gallons

- Run air stripper @ 15 gallons per minute (gpm)

= 13,506 days or 36 years

- Run air stripper @ 10 gpm

= 20,258 days or 56 years

- Run air stripper @ 40 gpm

= 5065 days or 14 years

Faster extraction and treatment takes less time.

Depth required for extraction wells = 45 feet.

**APPENDIX Q**

**COST ESTIMATES OF  
REMEDIAL ALTERNATIVES**

Table Q-1. Cost Estimate for Groundwater Alternative 1 - No Remedial Action,  
Water Use Restrictions, and Long Term Monitoring

Element/Item	Quantity	Unit	Unit Cost	Total Cost
<b>CAPITAL:</b>				
<b>Direct Cost</b>				
Monitor Well Construction (5 Wells)				
Drilling - 6" OD HSA	205	FT	\$25.00	\$5,125
Casing - PVC 4"	137	FT	\$7.20	\$989
Screen - PVC 4"	68	FT	\$10.40	\$704
Filter Pack - 100/weight	50	CF	\$6.26	\$313
Bentonite Pellets	504	LBS	\$0.17	\$86
Surface Pad - Concrete	20	CF	\$20.00	\$400
Cap - Locking	5	EA	\$25.00	\$125
Well Development	14	HR	\$150.00	\$2,100
Water Tank	5	DAY	\$250.00	\$1,250
Mobilization	1	LS	\$2,500.00	\$2,500
Decon / Standby	1	LS	\$2,000.00	\$2,000
			<b>SUB TOTAL</b>	<b>\$15,591</b>
<b>Indirect Cost</b>				
Review Documents (Well Locating)	40	HR	\$90.00	\$3,600
Modeling (Well Locating)	120	HR	\$90.00	\$10,800
Specifications and Bid Review	80	HR	\$50.00	\$4,000
Well Survey	20	HR	\$50.00	\$1,000
			<b>SUB TOTAL</b>	<b>\$19,400</b>
<b>TOTAL CAPITAL COST</b>				<b>\$34,991</b>
<b>O&amp;M</b>				
<b>Annual</b>				
Monitoring (quarterly)				
Sampling - Analytical	40	EA	\$600.00	\$24,000
Sampling - Labor	50	HR	\$50.00	\$2,500
Report	40	HR	\$50.00	\$2,000
			<b>SUB TOTAL</b>	<b>\$28,500</b>
<b>Periodic Costs (every 5 years)</b>				
Site Review and Public Health Assmnt.	120	HR	\$75.00	\$9,000
			<b>SUB TOTAL</b>	<b>\$9,000</b>
<b>PRESENT WORTH (5% over 30 years; 3% inflation/yr)</b>				
Present Worth Capital				\$34,991
Present Worth Annual O&M				\$694,783
Present Worth Periodic O&M				\$39,091
Contingencies (15%)				\$115,330
<b>TOTAL PRESENT WORTH</b>				<b>\$884,195</b>

**Table Q-2. Cost Estimate for Groundwater Alternative 2 - Groundwater Extraction,  
and Discharge to Storm Drain**

Element/Item	Quantity	Unit	Unit Cost	Total Cost
CAPITAL:				
Direct Cost				
Recovery Well Construction (33 Wells)				
Drilling - 10" OD HSA	1485	FT	\$30.00	\$44,550
Casing - PVC 4"	995	FT	\$7.20	\$7,164
Screen - Screen 4"	490	FT	\$10.40	\$5,097
Filter Pack - 100/weight	495	CF	\$6.26	\$3,099
Bentonite Pellets	3300	LBS	\$0.17	\$561
Surface Pad - Concrete	132	CF	\$20.00	\$2,640
Submersible Pump - 1.5 HP	33	EA	\$500.00	\$16,500
Well Development	131	HR	\$150.00	\$19,693
Water Tank	37	DAY	\$250.00	\$9,372
Mobilization	1	LS	\$5,000.00	\$5,000
Connection to Storm Drain	1	LS	\$3,500.00	\$3,500
Decon / Standby	1	LS	\$2,000.00	\$2,000
Sub total Recovery Well Construction				\$119,175
Treatment System				
Site Preparation	18	AC	\$1,100.00	\$19,800
Pre-fab Treatment Bldg.	2	EA	\$30,000.00	\$60,000
Air Stripping Tower	1	EA	\$35,000.00	\$35,000
Control Panel, Conduit, & Appurt.	2	EA	\$15,000.00	\$30,000
Integrating Controls for Well	2	LS	\$8,000.00	\$16,000
Well Accesories (valves, gauges, etc.)	33	EA	\$100.00	\$3,300
Discharge Pump & Appurtenances	2	EA	\$16,000.00	\$32,000
PVC Force Main (intake) - 8"	900	LF	\$28.00	\$25,200
PVC Force Main (discharge) - 8"	200	LF	\$28.00	\$5,600
Air Release Assembly	2	EA	\$1,200.00	\$2,400
Transformer	1	EA	\$18,000.00	\$18,000
Electrical Connection	1	LS	\$15,000.00	\$15,000
Electric line	500	FT	\$60.00	\$30,000
Sub Total Treatment System				\$292,300
Total Direct Cost:	SUB TOTAL			\$411,475
Indirect Cost				
Review Documents (Well locating)	40	HR	\$90.00	\$3,600
Modeling (Well locating)	120	HR	\$90.00	\$10,800
Pump Test (Well locating)	1	LS	\$4,000.00	\$4,000
License and Permitting	1	LS	\$12,000.00	\$12,000
Specs & Bid Review	40	HR	\$90.00	\$3,600
Startup & Shakedown Cost	2	WK	\$5,500.00	\$11,000
SUB TOTAL				\$45,000
TOTAL CAPITAL COST				\$456,475

Table Q-2 (Continued)

Element/Item	Quantity	Unit	Unit Cost	Total Cost
<b>O&amp;M</b>				
<b>Annual</b>				
Labor	2000	HR	\$50.00	\$100,000
Electricity	12	MNTH	\$2,162.00	\$25,944
Materials	12	MNTH	\$100.00	\$1,200
<b>Monitoring (weekly)</b>				
Sampling - Analytical	52	EA	\$33.00	\$1,716
Sampling - Labor	52	HR	\$50.00	\$2,600
Report	96	HR	\$50.00	\$4,800
			<b>SUB TOTAL</b>	<b>\$136,260</b>
<b>Periodic Costs (every 5 years)</b>				
Site Review and Public Health Assmnt.	120	HR	\$75.00	\$9,000
			<b>SUB TOTAL</b>	<b>\$9,000</b>
<b>PRESENT WORTH (5% over 15 years; 3% inflation/yr)</b>				
Present Worth Capital				\$456,475
Present Worth Annual O&M				\$1,753,670
Present Worth Periodic O&M				\$22,345
Contingencies (15%)				\$334,873
Engineering (15%)				\$334,873
<b>TOTAL PRESENT WORTH</b>				<b>\$2,902,236</b>

**Table Q-3. Cost Estimate for Groundwater Alternative 3 - Groundwater Extraction,  
VOC's Removal, and Discharge to IWTP**

Element/Item	Quantity	Unit	Unit Cost	Total Cost
<b>CAPITAL:</b>				
<b>Direct Cost</b>				
Recovery Well Construction (33 Wells)				
Drilling - 10" OD HSA	1485	FT	\$30.00	\$44,550
Casing - PVC 4"	995	FT	\$7.20	\$7,164
Screen - PVC 4"	490	FT	\$10.40	\$5,097
Filter Pack - 100/weight	495	CF	\$6.26	\$3,099
Bentonite Pellets	3300	LBS	\$0.17	\$561
Surface Pad - Concrete	132	CF	\$20.00	\$2,640
Submersible Pump - 1.5 HP	33	EA	\$500.00	\$16,500
Well Development	131	HR	\$150.00	\$19,693
Water Tank	37	DAY	\$250.00	\$9,372
Mobilization	1	LS	\$5,000.00	\$5,000
Connection to WTP	1	LS	\$3,500.00	\$3,500
Decon / Standby	1	LS	\$2,000.00	\$2,000
Sub total Recovery Well Construction				\$119,175
Treatment System				
Site Preparation	18	AC	\$1,100.00	\$19,800
Pre-fab Treatment Bldg.	2	EA	\$30,000.00	\$60,000
Air Stripping Tower	1	EA	\$35,000.00	\$35,000
Control Panel, Conduit, & Appurt.	2	EA	\$15,000.00	\$30,000
Integrating Controls for Well	2	LS	\$8,000.00	\$16,000
Well Accesories (valves, gauges, etc.)	33	EA	\$100.00	\$3,300
Discharge Pump & Appurtenances	2	EA	\$16,000.00	\$32,000
PVC Force Main (intake) - 8"	900	LF	\$28.00	\$25,200
PVC Force Main (outlet) - 8"	200	LF	\$28.00	\$5,600
Air Release Assembly	2	EA	\$1,200.00	\$2,400
Transformer	1	LS	\$18,000.00	\$18,000
Electric line	500	FT	\$60.00	\$30,000
Electrical Connection	1	LS	\$15,000.00	\$15,000
Sub Total Treatment System				\$292,300
Total Direct Cost:			SUB TOTAL	\$411,475
Indirect Cost				
Review Documents (Well locating)	40	HR	\$90.00	\$3,600
Modeling (Well locating)	120	HR	\$90.00	\$10,800
Pump Test (Well locating)	1	LS	\$4,000.00	\$4,000
License and Permitting	1	LS	\$2,000.00	\$2,000
Specs & Bid Review	40	HR	\$90.00	\$3,600
Startup & Shakedown Cost	2	WK	\$5,500.00	\$11,000
SUB TOTAL				\$35,000
TOTAL CAPITAL COST				\$446,475

Table Q-3 (Continued)

Element/Item	Quantity	Unit	Unit Cost	Total Cost
O&M				
Annual				
Labor	2000	HR	\$50.00	\$100,000
Electricity	12	MNTH	\$2,162.00	\$25,944
Materials	12	MNTH	\$100.00	\$1,200
IWPT Costs	121,414	Kgal	\$1.50	\$182,120
Monitoring (weekly)				
Sampling - Analytical	52	EA	\$33.00	\$1,716
Sampling - Labor	52	HR	\$50.00	\$2,600
Report	96	HR	\$50.00	\$4,800
			SUB TOTAL	\$318,380
Periodic Costs (every 5 years)				
Site Review and Public Health Assmnt.	120	HR	\$75.00	\$9,000
			SUB TOTAL	\$9,000
PRESENT WORTH (5 % over 15 years; 3 % inflation/yr)				
Present Worth Capital				\$446,475
Present Worth Annual O&M				\$4,097,564
Present Worth Periodic O&M				\$22,345
Contingencies (15 %)				\$684,958
Engineering (15 %)				\$684,958
TOTAL PRESENT WORTH				\$5,936,299



Table Q-4. Cost Estimate for Groundwater Alternative 4 - Groundwater Extraction, Infiltration Gallery, and Microbial Degradation

Element/Item	Quantity	Unit	Unit Cost	Total Cost
<b>CAPITAL:</b>				
<b>Direct Cost</b>				
Recovery Well Construction (33 Wells)				
Drilling - 10" OD HSA	1485	FT	\$30.00	\$44,550
Casing - PVC 4"	995	FT	\$7.20	\$7,164
Screen - PVC 4"	490	FT	\$10.40	\$5,097
Filter Pack - 100/weight	495	CF	\$6.26	\$3,099
Bentonite Pellets	3300	LBS	\$0.17	\$561
Surface Pad - Concrete	132	CF	\$20.00	\$2,640
Submersible Pump - 1.5 HP	33	EA	\$500.00	\$16,500
Well Development	131	HR	\$150.00	\$19,693
Water Tank	37	DAY	\$250.00	\$9,372
Mobilization	1	LS	\$5,000.00	\$5,000
Decon / Standby	1	LS	\$2,000.00	\$2,000
Sub total Recovery Well Construction				\$115,675
Treatment System				
Site Preparation	18	AC	\$1,100.00	\$19,800
Pre-fab Treatment Bldg	2	EA	\$30,000.00	\$60,000
Air Stripping Tower	1	EA	\$35,000.00	\$35,000
Control Panel, Conduit, & Appurt.	2	EA	\$15,000.00	\$30,000
Integrating Controls for Well	2	LS	\$8,000.00	\$16,000
Well accesories (valves, gauges, etc.)	33	EA	\$100.00	\$3,300
Discharge Pump & Appurtenances	2	EA	\$16,000.00	\$32,000
PVC Force Main (intake) - 8"	900	LF	\$28.00	\$25,200
PVC Force Main (outlet) - 8"	200	LF	\$28.00	\$5,600
Air Release Assembly	2	EA	\$1,200.00	\$2,400
Transformer	1	LS	\$18,000.00	\$18,000
Electric line	1000	FT	\$60.00	\$60,000
Electrical Connection	1	LS	\$15,000.00	\$15,000
Sub Total Treatment System				\$322,300
Infiltration Gallery (12'x12'x3')	3	EA	\$6,325.00	\$18,975
Sub Total Infiltration Gallery				\$18,975
Total Direct Cost:			SUB TOTAL	\$456,950
Indirect Cost				
Review Documents (Well locating)	80	HR	\$90.00	\$7,200
Modeling (Well locating)	240	HR	\$90.00	\$21,600
Specifications and Bid Review	40	HR	\$90.00	\$3,600
Well Survey	88	HR	\$50.00	\$4,400
Biofeasibility analysis	1	LS	\$10,000.00	\$10,000
SUB TOTAL				\$46,800
TOTAL CAPITAL COST				\$503,750

Table Q-4 (Continued)

Element/Item	Quantity	Unit	Unit Cost	Total Cost
<b>O&amp;M</b>				
<b>Annual</b>				
Labor	2000	HR	\$50.00	\$100,000
Electricity	12	MNTH	\$2,162.00	\$25,944
Materials	12	MNTH	\$100.00	\$1,200
<b>Monitoring (weekly)</b>				
Sampling - Analytical	52	EA	\$33.00	\$1,716
Sampling - Labor	52	HR	\$50.00	\$2,600
Report	96	HR	\$50.00	\$4,800
			<b>SUB TOTAL</b>	<b>\$136,260</b>
<b>Periodic Costs (every 5 years)</b>				
Site Review and Public Health Assmnt.	120	HR	\$75.00	\$9,000
			<b>SUB TOTAL</b>	<b>\$9,000</b>
<b>PRESENT WORTH (5% over 15 years; 3% inflation/yr)</b>				
Present Worth Capital				\$503,750
Present Worth Annual O&M				\$1,753,670
Present Worth Periodic O&M				\$22,3
Contingencies (15%)				\$341,965
Engineering (15%)				\$341,965
<b>TOTAL PRESENT WORTH</b>				<b>\$2,963,694</b>

Table Q-5. Cost Estimate for Groundwater Alternative 5 - Air Sparging/  
Vapor Extraction

Element/Item	Quantity	Unit	Unit Cost	Total Cost
<b>CAPITAL:</b>				
<b>Direct Cost</b>				
Air Injection/Extraction Well Construction (108 Wells)				
Drilling - 10" OD HSA	3145	FT	\$30.00	\$94,350
Casing - PVC4"	2107	FT	\$7.20	\$15,170
Screen - PVC-4"	1038	FT	\$10.40	\$10,795
Filter Pack - 100/weight	1295	CF	\$6.26	\$8,107
Bentonite Pellets	8634	LBS	\$0.17	\$1,468
Surface Pad - Concrete	345	CF	\$20.00	\$6,900
Well Development	432	HR	\$150.00	\$64,800
Water Tank	123	DAY	\$250.00	\$30,750
Mobilization	1	LS	\$29,659.00	\$29,659
Sub total Recovery Well Construction				\$261,999
Treatment System				
Site Preparation	18	AC	\$1,100.00	\$19,800
Pre-fab Treatment Building	1	EA	\$519,100.00	\$519,100
Air Compressors	1	EA	\$53,300.00	\$53,300
Vapor Extraction Blower	1	EA	\$2,800.00	\$2,800
Control Panel, Conduit, & Appurt.	2	EA	\$15,000.00	\$30,000
Integrating Controls for Well	2	LS	\$8,000.00	\$16,000
Well accesssories (Valves, gauges,etc)	108	EA	\$100.00	\$10,800
Air Dryer/Demister	1	EA	\$2,500.00	\$2,500
Activated Carbon Adsorbers	1	LS	\$17,000.00	\$17,000
PVC Force Main (injection) 8"	2970	LF	\$28.00	\$83,160
PVC Force Main (extraction) 8"	2970	LF	\$28.00	\$83,160
Transformer	1	LS	\$18,000.00	\$18,000
Electrical Connection	1	LS	\$15,000.00	\$15,000
Electric Line	1000	LF	\$60.00	\$60,000
Sub Total Treatment System				\$930,620
Total Direct Cost:			SUB TOTAL	\$1,192,619
<b>Indirect Cost</b>				
Well Locating				
Review Documents	160	HR	\$50.00	\$8,000
Modeling	480	HR	\$60.00	\$28,800
Specifications and Bid Review	320	HR	\$50.00	\$16,000
Well Survey	176	HR	\$50.00	\$8,800
SUB TOTAL				\$61,600
TOTAL CAPITAL COST				\$1,254,219

Element/Item	Quantity	Unit	Unit Cost	Total Cost
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Table Q-5 (Continued)

O&M

Annual

Labor	4160	HR	\$50.00	\$208,000
Electricity	12	MNTH	\$2,700.00	\$32,400
Materials	12	MNTH	\$500.00	\$6,000

Monitoring (weekly)

Sampling - Analytical	20	EA	\$600.00	\$12,000
Sampling - Labor	20	HR	\$50.00	\$1,000
Report	96	HR	\$50.00	\$4,800

SUB TOTAL \$264,200

Periodic Costs (every 5 years)

Site Review and Public Health Assmnt.	120	HR	\$75.00	\$9,000
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SUB TOTAL \$9,000

PRESENT WORTH (5% over 15 years)

Present Worth Capital	\$1,254,219
Present Worth Annual O&M	\$2,742,306
Present Worth Periodic O&M	\$22,346
Contingencies (15%)	\$602,831

TOTAL PRESENT WORTH

\$4,621,701